DOCTORAL THESIS

Effects of valence and arousal on the allocation of attention to motivationally significant stimuli.

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Effects of Valence and Arousal on the Allocation of Attention to Motivationally Significant Stimuli

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ABSTRACT

Innate attentional mechanisms that prioritise the processing of potential threats and opportunities for satisfying basic primordial needs serve a highly adaptive function for an individual and the species. Existing research has revealed preferential spatial attention for threatening stimuli, including: (i) facilitated attentional engagement, (ii) delayed disengagement, and (iii) attentional avoidance. Theoretical models that have attempted to explain these phenomena are predicated on the assumption that a threat detection mechanism operates automatically to facilitate preferential processing of threatening information. According to motivational accounts of emotional processing, however, an adaptive attentional system should also prioritise high arousing, appetitive stimuli that are symbolic of our evolutionary needs. Although relatively unexplored, there is evidence to suggest that appetitive stimuli may also preferentially capture attention, with recent studies suggesting that stimulus arousal determines the allocation of cognitive resources, independent of valence.

To disentangle the effects of valence and arousal on visual attention, a novel set of motivationally significant pictures was developed. The pictures were validated in Study 1 using physiological indices of the orienting response, a precursory mechanism to attentional processing. Skin conductance responses (SCRs) and heart rate were measured while nonselect participants passively viewed threatening, appetitive, and neutral pictures that varied in arousal. Verbal ratings of valence, arousal, and interest were obtained following the viewing task. Irrespective of valence, SCRs and cardiac deceleration were greatest for high arousing pictures (blood injuries and heterosexual erotica) relative to low arousing pictures (human aggression and nurturance of offspring), suggesting that orienting is augmented on the basis of stimulus arousal. The physiological indices were found to share a strong

association with verbal ratings of arousal, even after controlling for subjective interest. Arguing against threat-superiority theories, orienting responses did not vary as a function of valence.

The picture stimuli were subsequently employed in a series of spatial cueing experiments designed to examine the individual and interactive effects of stimulus valence and arousal on the distinct components of spatial attention. Pictures preceded probes that appeared in either cued (valid trials) or non-cued locations (invalid trials) to capture the effects of valence and arousal on attentional engagement and disengagement, respectively. The exposure duration of the pictures varied between 24 ms and 1000 ms in order to clarify the time-course of these effects. All experiments were conducted using nonselect samples, and individual differences in state and trait anxiety were statistically controlled.

In Study 2, latencies for responding to the probe's location indexed the allocation of spatial attention. Reaction times were slower on valid trials, indicative of inhibition of return. Even when the cues predicted the location of the probe on 75% of trials (Experiment 2.2), and the exposure duration of the cues was reduced to $\leq$ 100 ms (Experiment 2.3), valid cues failed to prompt faster responses. Contrary to predictions that high arousing pictures would facilitate attention to the probes on valid trials relative to neutral pictures, results indicated inhibited engagement of these stimuli between 100-1000 ms post-stimulus onset (Experiments 2.1 & 2.2). Although these findings suggest that attention avoided the high arousing cues, the same pictures produced slower responses on invalid trials, indicative of delayed disengagement, as did the less arousing, threatening pictures. These discordant findings were explained in terms of distinct effects of stimulus arousal on perception and attentional shifting. On valid trials, perception of the cues may have interfered

with detection of the probes due to the overlapping configuration of the stimuli, thereby masking facilitated engagement effects. Perceptual competition is less likely to have occurred when the cues and probes were spatially distinct on invalid trials, supporting interpretations that attention was slower to disengage the high arousing pictures. A second series of spatial cueing studies was conducted to test this interpretation.

In Study 3, a more demanding probe classification task was employed and the spatial configuration of the cues relative to the probes was amended to eliminate spatial overlap. Following these methodological changes, a robust cue validity effect was observed, characterised by faster responding on valid trials. In support of threat-superiority theories, facilitated engagement of high arousing, threatening pictures was observed at 24 ms post-stimulus onset (Experiment 3.1). Although a general slowing effect of stimulus arousal on the speed of responding was observed irrespective of exposure duration, there was no evidence that attentional disengagement was influenced by the affective qualities of the pictures. Delayed disengagement effects were absent even when the cues accurately predicted the location of probe on 75% of trials (Experiment 3.2), and the exposure duration of the cues was increased to 100-400 ms (Experiment 3.3). In contrast to the comparatively simple localisation task employed in Study 2, classification of the probes is assumed to have placed greater demands on top-down, attentional control that attenuated the effects of arousal on attentional shifting. The deleterious effects of high stimulus arousal on non-spatial components of attention (i.e., processing speed and capacity), however, appear to be more resistant to attentional control, as demonstrated by a general effect of stimulus arousal. Because arousal-driven interference was observed in the absence of delayed disengagement, these appear to be dissociable effects,

supporting conclusions that stimulus arousal influences both spatial and non-spatial aspects of visual attention, depending on contextual demands.

The results of Study 2 and 3 were interpreted with respect to existing models of attention to emotional stimuli. An integrated model is proposed that accounts for the effects of both valence and arousal on the allocation of attention according to the findings of the current research and existing literature. Limitations of the research are also discussed and directions for future studies are suggested.

Keywords: emotion, visual attention, spatial cueing, motivational significance, valence, arousal, threat

DECLARATION OF ORIGINALITY

This thesis is submitted to Bond University in fulfilment of the requirements of the degree of Doctor of Philosophy (PhD). This thesis represents my own original work towards this research degree and contains no material which has been previously submitted for a degree or diploma at this University or any other institution, except where due acknowledgement is made. All raw data and analyses have been retained and are available upon request. I certify that I have made and retained a copy of this document.

Name: James C. Champion

Signature:

Date: 22 December 2016

RESEARCH OUTPUTS & PUBLICATIONS

Journal Publications

Edwards, M .S., Moore, P. , Champion, J. C., Edwards, E. J. (2014). Effects of trait anxiety and situational stress on attentional shifting are buffered by working memory capacity. *Anxiety, Stress, and Coping*, 28, 1-16. doi: 10.1080/10615806.2014.911846

Pidgeon, A., Lacota, K., & Champion, J. (2013). The moderating effects of mindfulness on psychological distress and emotional eating behaviour. *Australian Psychologist,* 48, 262–269. doi: 10.1111/j.1742-9544.2012.00091.x

Conference Proceedings

Champion, J. C., & Bitsika, V. (2013, July). *Sensory processing and cognitive functioning in autism spectrum disorders*. Paper presented at the 18th biennial conference of the Australasian Human Development Association, Gold Coast, Australia.

Champion, J. C., Edwards, M. S., Lyvers, M. (2014, April). *Physiological orienting during passive picture viewing: The role of stimulus valence and arousal*. Poster presented at the 41st annual meeting of the Australasian Experimental Psychological Society, Brisbane, Australia.

Champion, J. C., Edwards, M. S., Lyvers, M. (2014, April). *The effects of stimulus valence and arousal on early attentional processes*. Paper presented at the 41st annual meeting of the Australasian Experimental Psychological Society, Brisbane, Australia.

ETHICS DECLARATION

The research reported in this thesis received ethics approval from the Bond University Human Research Ethics Committee (BUHREC). Ethics application number RO1607.

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LIST OF ABBREVIATIONS

ADM……..Affective decision mechanism

ANOVA…….Analysis of variance

ANCOVA….. Analysis of covariance

CPU……Central processing unit

CRT……Cathode ray tube

CVI…….Cue validity index

ERP……Event-related potential

GES……Goal engagement system

HAA……...High arousing appetitive

HAT……... High arousing threatening

HR……..Heart rate

Hz……...Hertz

IAPS……...International Affective Picture System

IoR……. Inhibition of return

LAA……...Low arousing appetitive

LAT……....Low arousing threatening

M……Mean

ms……...Milliseconds

OR……..Orienting response

PRT……Picture rating task

RAM……..Resource allocation mechanism

RT……..Reaction time

SAM……...Self-Assessment-Manikin

SCR……Skin conductance response

SCT……Spatial cueing task

SD……...Standard deviation

SOA……..… Stimulus onset asynchrony

STAI-S……... State Anxiety Scale of the State-Trait Anxiety Inventory

STAI-T……... Trait Anxiety Scale of the State-Trait Anxiety Inventory

TES…… Threat evaluation system

VES……Valence evaluation system

PREFACE

Over 95% of human existence has been spent living in the open savannah in small hunter-gatherer bands (Lee & Daly, 1999). The survival of our hominid ancestors depended largely on their ability to negotiate adaptive challenges, such as locating sources of food, forging shelter, and evading predators. In response to recurrent adaptive problems, *Homo sapiens* evolved efficient neurocognitive mechanisms for detecting and responding to stimuli relevant to individual survival (LeDoux, 2012). An innate capacity for self-preservation, however, was not the sole contributor to our evolutionary success. Individual survival supports the evolution of a species insofar as it allows opportunity for procreation and rearing of progeny (Tooby & Cosmides, 2008). The probability that our genes will be propagated onto successive generations is contingent on reproductive strategies that involve pursing potential mating partners and fending off sexual rivals, in addition to parental investment aimed at ensuring the survival and reproductive success of one's offspring.

For all forms of life, even single-celled organisms, survival necessitates mechanisms for detecting and responding to aversive and appetitive stimuli (Schneirla, 1959). Bacteria, for example, have been shown to avoid noxious agents and approach nutrients in order to grow (Macnab & Koshland, 1972). Whereas avoidance functions to protect an organism from sources of harm and danger, approach behaviours reflect hedonistic drives that promote growth and reproduction (Lang & Bradley, 2013). In vertebrates, these primitive approach-avoidance tendencies have been attributed to the *reptilian forebrain* (basal ganglia), which initiates basic survival behaviours, including fighting, fleeing, feeding, and fornication (MacLean, 1952, 1990). During the course of evolution, the divergence

of mammals from reptiles resulted in the development of the *paleomammalian brain* (limbic system), which brought with it more elaborative mechanisms for evaluating and responding to adaptive pressures (MacLean, 1952, 1990). Through innate emotional and motivational systems, the paleomammalian brain allowed organisms to respond to incoming stimuli on the basis of instinct and previous encounters, while giving rise to psychological experiences of emotion (LeDoux, 2012; Panksepp, 2008).

In The Expression of the Emotions in Man and Animals, Darwin (1872) proposed that the process of evolution by natural selection can be applied to psychological phenomena. In the same way that anatomical structures evolved over time to aid survival and reproduction, Darwin claimed that emotions can be explained in terms of their functional properties for negotiating adaptive pressures faced by our hunter-gatherer ancestors. From a functionalist standpoint, emotions are action dispositions that prioritise adaptive behaviour in response to environmental demands (Ekman, 1992a; Levenson, 1994; Löw, Lang, Smith, & Bradley, 2008). Indeed, the word "emotion" is derived from the Latin *emovere*, meaning to move. By activating or inhibiting electrochemical processes within the nervous and endocrine systems, emotions can be regarded as functionally specialised programs that orchestrate changes in perception, cognition, and physiology (Tooby & Cosmides, 2008; Toronchuk & Ellis, 2012). For example, the emotion of fear that occurs in response to an approaching predator may heighten sensory acuity, prompt recollections of similar encounters, and mobilise the body for fleeing or fighting.

Despite the vastly different conditions of contemporary society compared to the environment inhabited by our evolutionary predecessors, the emotional-cognitive architecture of modern humans remains influenced by ancestral priorities. Cues

associated with biologically-prepared threats, such as pictures of snakes and spiders, are rapidly detected, even in young children with no prior experience or knowledge about the potential danger of such animals (LoBue, 2010, 2014; LoBue & DeLoache, 2008, 2010). Similarly, infants show gaze preferences for smiling and attractive faces compared to neutral and unattractive faces (Grossmann, Striano, & Friederici, 2007; Langlois et al., 1987). Thus, it appears that natural selection has endowed us with innate aversions and preferences that are driven by biological imperatives.

CHAPTER I

INTRODUCTION

Given the wealth of sensory input competing for an individual's limited processing resources, adaptive behaviour necessitates efficient neurocognitive systems that prioritise environmental stimuli on the basis of current needs, goals and environmental demands (Desimone & Duncan, 1995; Serences & Yantis, 2006). From an evolutionary standpoint, an attentional system that preferences cues of potential threat to one's physical wellbeing and opportunities for satisfying basic primal needs from relatively innocuous sources of sensory input has obvious adaptive value. Such biases can facilitate rapid appraisal and responding to situations that are relevant to individual survival and preservation of the species, assisting an organism to avoid predators and other dangers, locate prey, forage for food, and pursue potential mating partners (Bradley, 2009; Lang, Bradley, & Cuthbert, 1997, 1998).

Not unlike a spotlight scanning the visual field, spatial attention involves the shifting of attention to a location occupied by a stimulus, which is then engaged for the purpose of amplifying stimulus inputs and facilitating further processing (Cave & Bichot, 1999; Posner, 1980; Posner & Cohen, 1984; Yiend, 2010). In addition to shifting and engagement, spatial orienting also involves disengagement, a process whereby attention is withdrawn from a stimulus, followed by inhibition of return (IoR), which temporarily prevents attention from returning to an already attended to location (Klein, 2000; Posner & Cohen, 1984). According to current theoretical perspectives, spatial attention is directed on the basis of competition between top-down, endogenous processes and bottom-up, stimulus-driven factors (Desimone & Duncan, 1995; Kastner & Ungerleider, 2000, 2001). Highlighting the role of

endogenous processes, individuals are typically faster at detecting an object when informed about its features or location (Egeth, Virzi, & Garbart, 1984; Posner, Snyder, & Davidson, 1980). For example, when trying to locate a friend in a crowd, attention can preference specific features, such as hair colour and height. Such observations demonstrate that attention can be volitionally directed in accordance with current goals and previous knowledge (Yantis, 2000). Bottom-up processes that are responsive to stimulus features can also influence attention by interrupting current focus and redirecting the allocation of processing resources (Theeuwes, 1994; Yantis & Jonides, 1984). Exogenous factors which can attract attention include physical properties that increase the perceptual salience of a stimulus, such as brightness or shape (Jonides & Yantis, 1988). Such properties can attract rapid, involuntary attention, irrespective of intention.

A third factor that has shown to influence attentional selection concerns the emotional content of a stimulus (Brosch, Pourtois, Sander, & Vuilleumier, 2011; Lang, 1995; Pourtois, Schettino, & Vuilleumier, 2013; Vuilleumier, 2005; Yiend, 2010). Considering their relevance to survival, it is not surprising that affectively valenced stimuli have shown to elicit preferential attention, with evidence of enhanced orienting toward negative and positive words (Dresler, Mériau, Heekeren, & Van der Meer, 2009; Phaf & Kan, 2007), emotive facial expressions (Fox, Russo, & Dutton, 2002), provocative pictures (Vogt, Houwer, Koster, Van Damme, & Crombez, 2008), and cues of aversive events (Koster, Crombez, Van Damme, Verschuere, & De Houwer, 2004), when compared with affectively neutral stimuli (see Yiend, 2010 for a review). Similar to bottom-up processing, attention for emotional stimuli seems to occur rapidly and outside of volitional control (Brosch et

al., 2011; Pool, Brosch, Delplanque, & Sander, 2016; Pourtois, Schettino, & Vuilleumier, 2013; Vuilleumier, 2015).

Although emotionally provocative stimuli may attract preferential attention due to their inherent associations with aversive or desired consequences, the mechanisms underlying such biases continues to be contended. According to the evolutionary threat hypothesis, natural selection has resulted in attentional mechanisms that preferentially process stimuli representing phylogenetic threats to survival (Öhman, Flykt, & Esteves, 2001; Öhman & Mineka, 2001). The notion of a threat-superiority bias infers that attentional prioritisation is determined predominantly by stimulus valence, ranging along a continuum from extremely pleasurable to extremely aversive, and assumes that rapid detection of negatively valenced and potentially threatening stimuli is more crucial to survival than the detection of opportunities for satisfying biological needs, such as hunger, thirst, and sex (Öhman, Flykt et al., 2001; Öhman, Lundqvist, & Esteves, 2001; Pratto & John, 1991; Robinson, 1998).

Others have argued that an attentional system which responds rapidly, but exclusively, to threatening stimuli would not be fully adaptive, as functional behaviour necessitates immediate responses to stimuli that offer opportunities for appetitive consequences and gratifying primordial needs (Anderson, 2013; Derryberry & Rothbart, 1997; Pessoa, 2015; Pool et al., 2016). The arousal hypothesis proposes that the degree of subjective and autonomic arousal elicited by a stimulus underlies attentional orienting, with more arousing stimuli eliciting preferential attention, independent of valence (Anderson, 2005; Mather & Sutherland, 2011; Schimmack, 2005; Russell, 1980). According to this account, both

threatening *and* appetitive stimuli can prompt preferential attention if sufficiently arousing.

The focus of the current thesis was to investigate how emotional stimuli influence the allocation of spatial attention along the time-course of information processing, by clarifying which affective dimensions the components of attentional orienting are sensitive to. Chapter II compares the theoretical models that have been developed to explain preferential allocation of attention to affective stimuli. Experimental paradigms employed to test these theories are summarised in Chapter III, including their key findings and respective limitations. In Chapter IV, the first empirical chapter, a novel set of affective pictures is validated using verbal ratings of valence, arousal, and interest, coupled with physiological indices of autonomic orienting. Thereafter, the affective stimulus set was employed across a series of spatial cueing experiments to determine the separate and interactive effects of stimulus valence and arousal on spatial attention, as described in Chapter V. By systematically varying the exposure duration of the pictures and their relevance to the task, the distinct components of spatial attention were examined, including engagement, disengagement, and IoR. A series of experiments employing a relatively simple probe localisation task are also reported in Chapter V. This version of the task was intended to examine attention for the affective pictures, while minimal demands were placed on attentional resources. In another series of experiments, reported in Chapter VI, participants completed a more demanding probe classification task and the spatial configuration of the stimuli was amended to minimise perceptual competition. In Chapter VII, the findings derived from these experiments are discussed and reconciled with existing theories. An integrated model is proposed that accounts for the effects of both valence and arousal on the allocation

of attention according to the findings of the current research and existing literature. Finally, the limitations of the thesis are identified and recommendations for future research are offered.

CHAPTER II

THEORETICAL PERSPECTIVES

Although preferential allocation of attention to affective stimuli can be of adaptive value by facilitating detection of possible threats to one's wellbeing and opportunities relevant to self-preservation and reproductive success, biased attention may also become maladaptive and play a role in the development and maintenance of psychopathological disorders. In particular, attentional biases toward threat-related stimuli have been found to be potentiated in individuals who are identified as being vulnerable to anxiety, in addition to those diagnosed with an anxiety-related condition, including Generalised Anxiety Disorder (Bradley, Mogg, White, Groom, & de Bono, 1999; Mogg & Bradley, 2005), Obsessive-Compulsive Disorder (Summerfeldt & Endler, 1998), Panic Disorder (Asmundson, Sandler, Wilson, & Walker, 1992; Ehlers, Margraf, Davies, & Roth, 1988; McNally, Riemann, & Kim, 1990), Post-Traumatic Stress Disorder (Buckley, Blanchard, & Neill, 2000), and phobias (Heinrichs & Hofmann, 2001; McNally, 1999; Musa & Lepine, 2000). In light of robust findings, preferential processing of threatening information is considered to reflect heightened vulnerability to clinically anxious states and has prompted the development of several theoretical frameworks attempting to explain the mechanisms underlying attentional biases (cf. Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007).

Information Processing Model (Beck & Clark, 1997; Clark & Beck, 2010)

The information processing model, depicted in Figure 2.1, claims that threatening stimuli can affect attention during both automatic and strategic stages of processing (Beck & Clark, 1997; Clark & Beck, 2010). At the preattentive level, an *orienting mode* operates outside of conscious awareness to facilitate rapid

engagement of potentially threatening stimuli. During this stage, the prioritisation of attention is determined by rapid registration of stimulus-driven factors, including valence and possible relevance to the individual (Clark & Beck, 2010). Once attention has engaged a negatively valenced stimulus, a *primal threat mode* is activated that promotes innate responses aimed at ensuring the individual's ongoing survival by maximising safety and minimising danger. Primal reactions include activation of the autonomic nervous system, behavioural mobilisation (i.e., defensive responses), in addition to cognitive biases that are focused on the potentially threatening stimulus and threat-oriented thoughts (Beck & Clark, 1997; Clark & Beck, 2010). During strategic stages of processing, *secondary elaboration* occurs. This stage is characterised by slow and effortful evaluation of the stimulus and the individual's capacity to cope with the perceived threat (Clark & Beck, 2010). While these processes operate, the stimulus is assumed to maintain attention, thereby delaying attentional disengagement. In non-anxious individuals, evaluative processes may deactivate the primal threat mode once the initial threat estimate is re-evaluated and the stimulus deemed to pose no immediate risk, thus allowing attention to reorient to other sources of input. If the initial threat estimation is increased, however, feedback to the primal threat mode is assumed to enhance autonomic arousal, sustain attentional engagement, and initiate defensive behaviours (Beck & Clark, 1997; Clark & Beck, 2010).

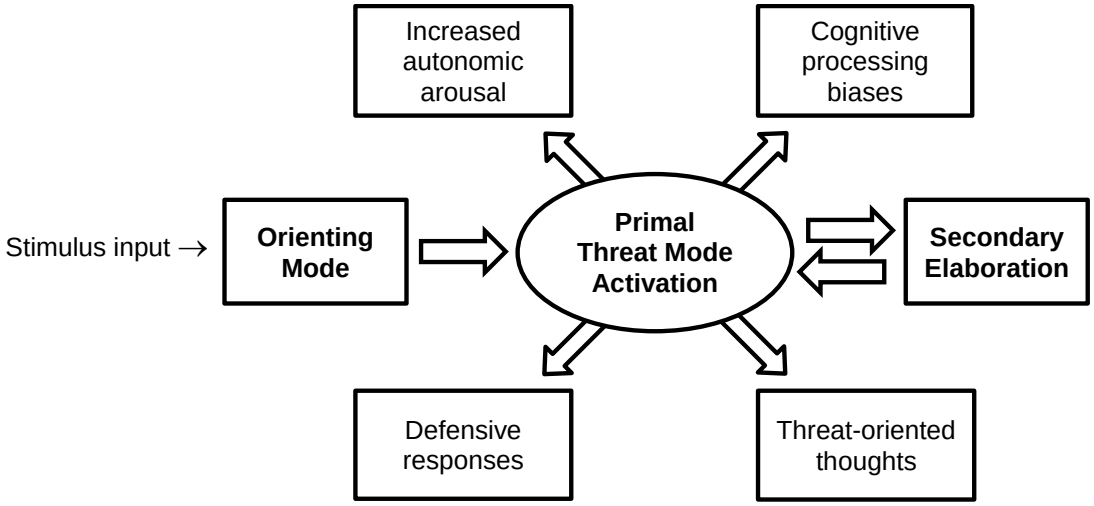

Figure 2.1. Information processing model (Beck & Clark, 1997; Clark & Beck, 2010).

Two-Stage Model (Williams, Watts, MacLeod & Mathews, 1988, 1997)

As illustrated in Figure 2.2, the two-stage model assumes that two mechanisms operate automatically to bias attention when an individual is confronted with a threatening stimulus. Firstly, an *affective decision mechanism* (ADM) appraises stimulus inputs in terms of threat value. This process is assumed to be moderated by state anxiety, including transient states of arousal, tension and worry, which increase the threat value output. If the degree of threat posed by a stimulus is appraised as being high, a *resource allocation mechanism* (RAM) is activated, which determines how additional attentional resources will be deployed. In contrast, if the threat value is appraised as being low, further processing of the stimulus is inhibited. How the RAM responds to threatening stimuli is assumed to be moderated by dispositional trait anxiety. The model predicts that high trait anxious individuals will orient their attention toward the threat, resulting in facilitated engagement. In contrast, as the degree of threat increases, low trait anxious individuals are predicted to divert attention away from the threatening stimulus, resulting in attentional

avoidance. Therefore, in response to input from the ADM, the RAM determines the direction of attentional bias on the basis of trait anxiety.

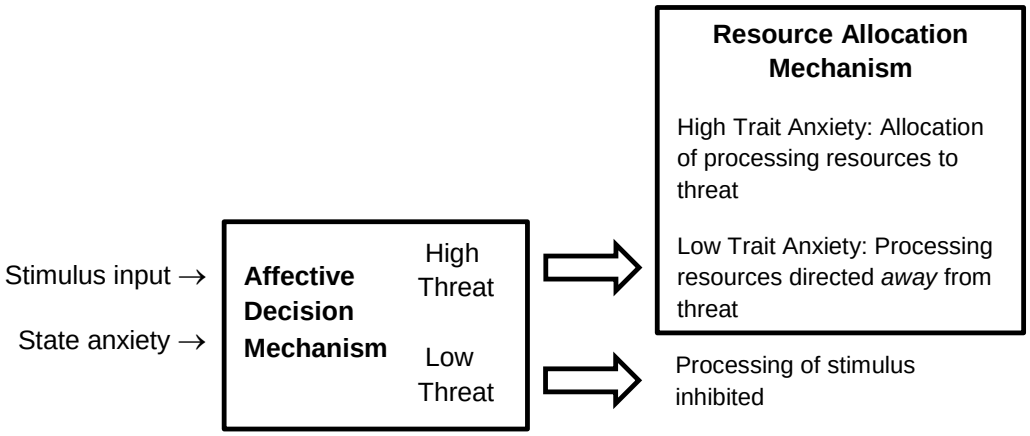

Figure 2.2. Two-stage model (Williams et al., 1988, 1997).

Although the two-stage model (Williams et al., 1988, 1997) has provided a useful framework for understanding the mechanisms of attentional bias, the assumption that low trait anxious individuals will divert attentional resources away from highly threatening stimuli is problematic. Attentional avoidance of intensely threatening stimuli is likely to be detrimental to physical wellbeing and survival. To be adaptive, an effective threat detection system must ensure that highly threatening stimuli receive preferential processing, irrespective of trait anxiety.

Cognitive-Motivational Model (Mogg & Bradley, 1998)

The cognitive-motivational model proposed by Mogg and Bradley (1998) proposes that attention to threatening stimuli is determined by two systems. As depicted in Figure 2.3, a *valence evaluation system* (VES) performs initial, preconscious evaluation of environmental stimuli by appraising potential threats and determining whether further allocation of attentional resources is warranted. In

addition to stimulus features, such as valence and biological preparedness, other factors can also influence the appraisal process, including situational context, prior experiences, and the individual's degree of state anxiety. Dispositional trait anxiety is also assumed to influence the reactivity of the VES to threat, with high trait anxious individuals exhibiting a tendency to appraise ambiguous or mildly threatening stimuli as highly threatening (Mogg & Bradley, 1998). Output from the VES activates a *goal engagement system* (GES), which mediates the allocation of processing resources. If a stimulus is appraised as highly threatening, current behaviour is interrupted and attention is directed toward the source of the threat. In contrast, if the VES identifies the stimulus as being of low threat, further processing is inhibited and current behaviour is maintained.

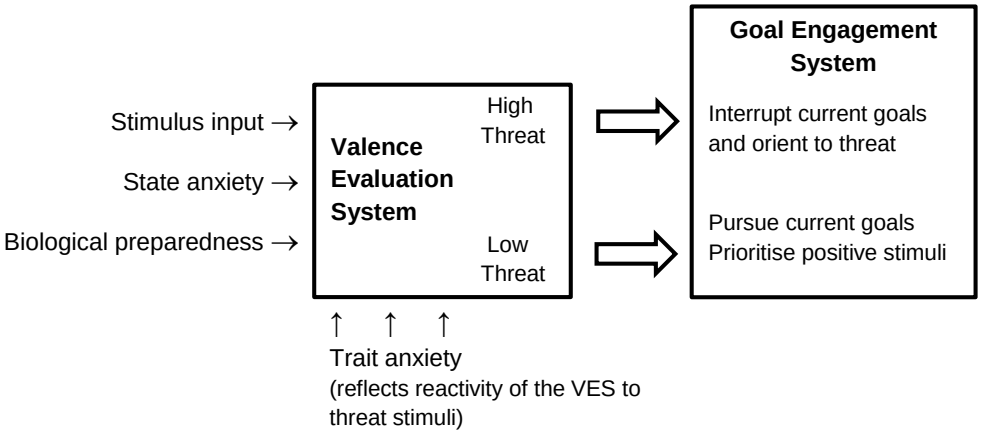

Figure 2.3. The cognitive-motivational model (Mogg & Bradley, 1998).

According to the cognitive-motivational model, high trait anxious individuals may be more prone to exhibiting attentional biases to mild or moderately threatening stimuli due to an overreactive VES. In the presence of highly threatening stimuli, however, the model predicts that both low and high trait anxious individuals will demonstrate attentional bias (Mogg & Bradley, 1998). Supporting the predictions of

the cognitive-motivational model, several studies have demonstrated that both high *and* low trait anxious individuals selectively attend to highly threatening pictures, while only high trait anxious participants selectively attend to moderately threatening pictures (Mogg et al., 2000; Wilson & MacLeod, 2003). In comparison to the two-stage model proposed by Williams et al. (1988, 1997), the assumptions made by the cognitive-motivational model are more consistent with intuitive predictions about the attentional processes engaged for non-anxious individuals in the presence of highly threatening information, that is, attentional orienting will be biased to highly threatening information, irrespective of anxiety.

Cognitive Model of Selective Processing (Mathews & Mackintosh, 1998)

In an attempt to explain how threatening stimuli may capture attention under some conditions, but inhibit attentional processing under others, Mathews and Mackintosh (1998) proposed a cognitive model of selective attention that emphasises the role of competition between stimulus inputs. As depicted in Figure 2.4, the model assumes that neural representations of stimuli compete for attentional resources within a competitive activation network. Like the ADM proposed by the two-stage model (Williams et al., 1988, 1997), and the VES proposed by the cognitive-motivational model (Mogg & Bradley, 1998), Mathews and Mackintosh (1998) claimed that a *threat evaluation system* (TES) operates automatically to evaluate stimulus inputs and enhance representations of stimuli identified as potentially threatening. If representations of threatening stimuli are stronger than competing representations, including those of task-relevant stimuli, the model predicts that attentional resources will be allocated to the source of the threat at the expense of concurrent tasks. Increases in both trait and state anxiety are assumed to lower the threshold of the TES. That is, higher anxiety is predicted to bias the

competitive network by enhancing activation to mild or moderately threatening stimuli. Consistent with the assumptions of the cognitive-motivational model (Mogg & Bradley, 1998), Mathews and Mackintosh (1998) predict that highly threatening stimuli will elicit preferential attention in all individuals, whereas milder threats will only receive preferential processing in anxious populations.

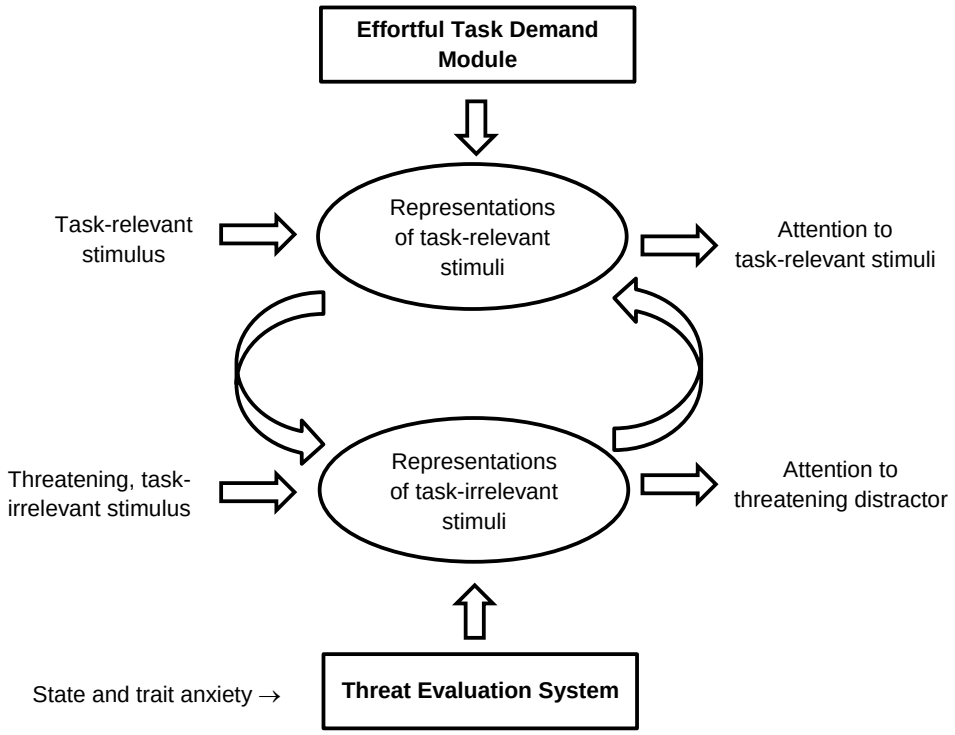

Figure 2.4. Cognitive model of selective processing (Mathews & Mackintosh, 1998).

One of the advantages of the cognitive model is that it also accounts for top-down, volitional effects on attention. Mathews and Mackintosh (1998) propose that interference caused by the TES can be influenced by voluntary efforts mediated by an *effortful task demand module*, which operates according to contextual demands. That is, attentional engagement of threatening stimuli may be inhibited by volitional efforts to attend to task-relevant stimuli. This assumption implies that endogenous

processes regulate the allocation of attention between cognitive goals and threatening stimuli that are irrelevant to current aims.

Evolved Fear Module (Öhman, 1996; Öhman & Mineka, 2001)

Whereas the models described previously were developed to explain how anxiety moderates the allocation of attention, Öhman and Mineka (2001) have proposed that attentional biases reflect the output of an *evolved fear module* that is shared by all species of mammals. The purpose of this evolutionary mechanism is to facilitate rapid detection and preferential processing of threats faced by our evolutionary ancestors, such as snakes, spiders, and angry facial expressions, thereby maximising the likelihood of adaptive responding and ultimately survival (Öhman, 1996; Öhman & Mineka, 2001). As illustrated in Figure 2.5, environmental stimuli are pre-attentively analysed by *feature detectors*. If features indicative of a biologically-prepared threat are detected, information is simultaneously forwarded onto a *significance evaluator* and an *arousal system*. Upon receiving input from the feature detectors, the arousal system initiates autonomic activity and may prompt attentional orienting in the absence of conscious awareness. On the basis of combined input from the arousal and feature detection systems, the significance evaluator can activate conscious processing, facilitating identification and appraisal of the threatening stimulus in addition to consideration of response options. During conscious stages of processing, an *expectancy system* also operates to facilitate comparisons with information stored in memory, including previous encounters with similar stimuli. If the encountered stimulus is perceived as threatening, conscious processing can then feed back to the arousal system, thereby increasing autonomic arousal.

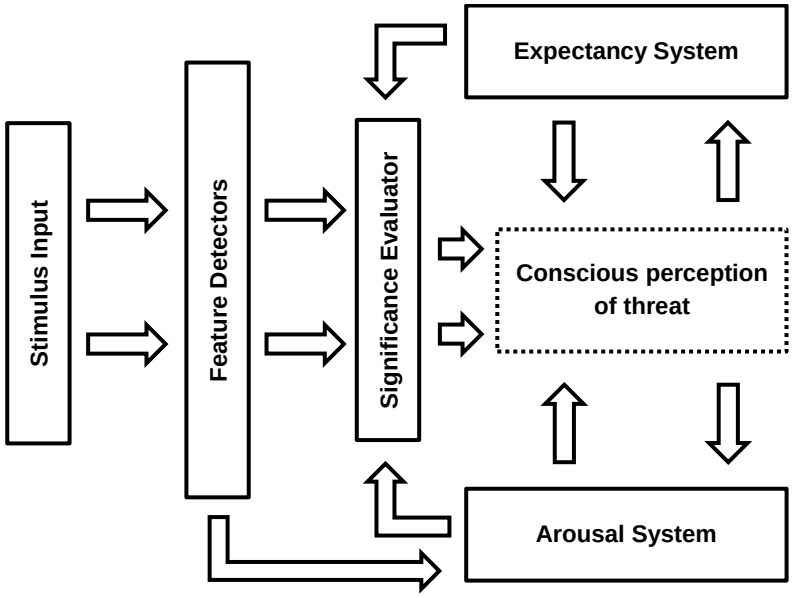

Figure 2.5. Evolved fear module (Öhman 1996; Öhman & Mineka, 2001).

A shared feature of the aforementioned models is that attentional prioritisation is predominantly determined by valence, which refers to the affective tone of a stimulus that can range from extremely pleasurable (positive valence) to extremely aversive (negative valence). Consistent with the assumption of a threat-superiority bias, neuroimaging studies have demonstrated that exposure to aversive pictures heightens activation of limbic structures, including the amygdala, in addition to extensive areas of the visual cortex, relative to benign stimuli (Davis & Whalen, 2001; Hariri, Tessitore, Mattay, Fera, & Weinberger, 2002). Through its connections with the hypothalamus and brainstem, the amygdala underlies emotional processing and the regulation of motivated behaviours, including the four *F*s (fighting, fleeing, feeding, and fornication; LeDoux, 2000; Sander, Grafman, & Zalla, 2003). Given its importance to survival, the amygdala is assumed to have evolved from subcortical structures of lower-order species that responded to primary reinforcers (Öhman & Mineka, 2001).

Dual-Route Model (LeDoux, 1996)

While investigating fear conditioning in rodents, LeDoux (1996) demonstrated that signals representing threatening stimuli are projected to the amygdala via two neural pathways, as shown in Figure 2.6. Representations of sensory input received by the retina are sent via the optic nerve to the thalamus. Although the thalamus is capable of recognising basic visual properties, it does not appear to be involved in object identification. A subcortical pathway operates automatically to project incoming sensory information directly from the thalamus to the amygdala, yielding rapid, but shallow processing of stimulus features that are consistent with previously encountered threats. The direct thalamic route has the advantage of speed, facilitating fast physiological and behavioural responses to potentially dangerous stimuli, including fight-or-flight reactions. In contrast, projections following the second pathway reach the amygdala indirectly via the visual cortex. Although this cortical route is comparatively slower, it facilitates more elaborate stimulus processing, accounting for contextual information and information stored in memory.

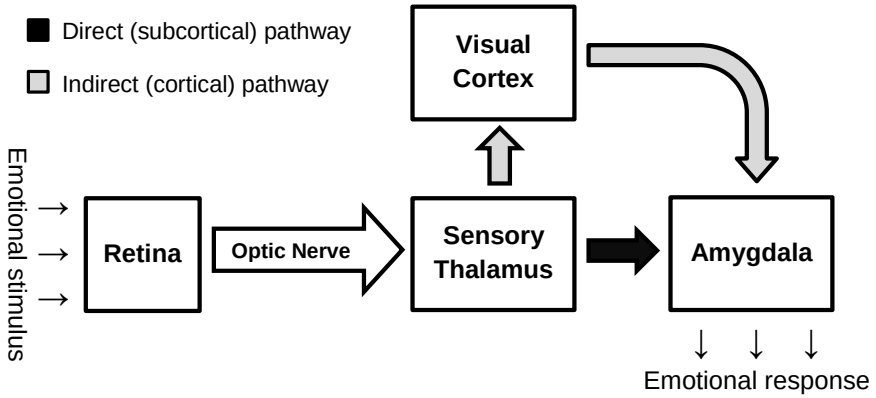

Figure 2.6. Direct and indirect pathways for processing threatening viusal stimuli (LeDoux, 1996).

With respect to the allocation of attention, the direct thalamic pathway might explain why attention automatically preferences threat-relevant stimuli at early stages of information processing (Carlson, Reinke, & Habib, 2009; Davis & Whalen, 2001; LeDoux, 2000; Öhman, 2005; Vuilleumier, Armony, Driver, & Dolan, 2001). During comparatively later stages, projections from the amygdala to the cortex are assumed to integrate with representations of threatening stimuli stored in memory, giving rise to conscious experiences of arousal and fear (LeDoux, 2000). As a consequence of these elaborative cortical processes, attentional engagement of the stimulus may be prolonged, delaying shifts of attention to other sources of input.

Since LeDoux's (1996) seminal research on fear conditioning, neuropsychological studies have demonstrated that cortico-limbic reactivity is not limited to negatively valenced information, with similar patterns of activation observed in response to viewing arousing appetitive stimuli, including erotic pictures and cues representing opportunities for reinforcement and reward (Bradley et al., 2003; Canli, Zhao, Brewer, Gabrieli, & Cahill, 2000; Garavan, Pendergrass, Ross, Stein, & Risinger, 2001; Kensinger & Schacter, 2006; Lewis, Critchley, Rotshtein, & Dolan, 2007; Murray, 2007; Sergerie, Chochol, & Armony, 2008). With the intention of explaining the cognitive mechanisms underlying clinical and subclinical anxiety, the aforementioned models adopt the notion of a threat-superiority bias and do not make explicit predictions regarding attention to pleasantly arousing or appetitive stimuli. The proposal of an evolved fear module (Öhman, 1996; Öhman & Mineka, 2001), for example, implies that early attentional orienting is directed exclusively toward biologically-prepared, threatening stimuli, and does not account for selective attention toward appetitive stimuli that may also be of evolutionary

significance. A holistic conceptualisation of how attention is modulated by affective stimuli necessitates additional modules to explain specific effects for other types of stimuli (Panksepp & Panksepp, 2000). For example, it has been proposed that the mammalian brain has evolved to include an expectancy-foraging system that is responsive to stimuli reflective of opportunities for primary reinforcement, reward and pleasure (Panksepp, 1992, 1998).

In addition to assuming that preferential processing of threatening stimuli is driven by automatic detection of stimulus valence (Beck & Clark, 1997; Clark & Beck, 2010; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Öhman, 1996; Öhman & Mineka, 2001; Williams et al., 1988, 1997), several models also make predictions regarding the influence of state anxiety and arousal. Mogg and Bradley (1998) propose that the sensitivity of the VES increases in response to heightened state anxiety, whereas Williams et al. (1988, 1997) suggest that state anxiety can mimic the effects of high threat input, thereby increasing the responsiveness of the ADM. Given that high arousing stimuli can elicit autonomic changes consistent with heightened state anxiety independently of valence, including increased electrodermal activity and decelerated heart rate (HR; Bradley, Codispoti, Cuthbert et al., 2001), it is plausible that the predictions made by these models may extend to high arousing, appetitive stimuli. For example, if increased autonomic arousal can increase the sensitivity of the significance evaluator, as predicted by Öhman and Mineka (1996, 2001), then high arousing stimuli containing appetitive features, such as pictures depicting sources of nourishment and reproductive opportunities, may elicit attentional biases similar to those observed for threatening stimuli.

Motivational Model of Emotion (Lang et al., 1997, 1998)

The importance of stimulus arousal on attention is highlighted by the prevailing models of emotion. Unlike the categorical approach, which attempts to reduce emotional phenomena into discrete affective states (Ekman, 1992b; Levenson, 2003), the dimensional approach decomposes emotion into two underlying dimensions, valence and arousal (Lang et al., 1997, 1998; Russell, 1980, 2003; Watson, Wiese, Vaidya, & Tellegen, 1999). As depicted in Figure 2.7, valence refers to the extent to which an emotional encounter is perceived as unpleasant versus pleasant, whereas arousal corresponds to the degree to which the emotional response is activated (low vs. high).

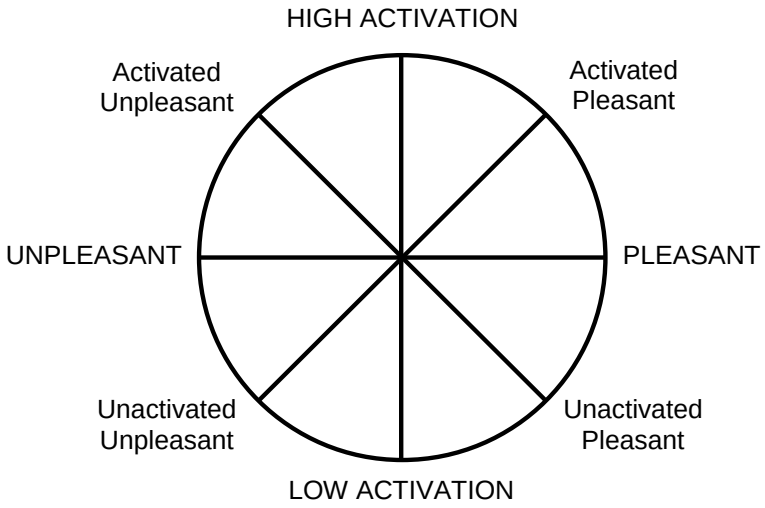

Figure 2.7. Circumplex model of emotion. Adapted from Russell (2003).

Accounting for enhanced neurocognitive sensitivity to threatening *and* appetitive stimuli, the motivational model of emotion (Lang et al., 1997, 1998) proposes that stimulus valence and arousal interact to determine the activation of two distinct motivational systems. A defensive system coordinates responses that serve to protect the organism, including withdraw, escape and attack behaviours, in the

presence of threatening stimuli. In contrast, encounters that promote self-preservation and propagation of the species, such as opportunities for nourishment, procreation and nurturance, activate the appetitive system, which facilitates approach behaviours, including ingestion, copulation and caregiving of offspring (Bradley, 2009; Bradley & Lang, 2007).

Activation of the motivational systems is initiated by feature comparisons between an encountered stimulus and representations of motivationally significant stimuli stored in memory (Bradley, Keil, & Lang, 2012). As shown in Figure 2.8, subjective judgments of hedonic valence (i.e., pleasure) correspond to which motivational system is engaged, whereas indices of stimulus arousal determine the degree of activation (Bradley & Lang, 2007; Lang et al., 1998). Accordingly, the detection of highly arousing threatening and appetitive stimuli prompts heightened activation of the defensive and appetitive motivational systems, respectively, which in turn mediate changes in autonomic activity to facilitate attentional orienting and ready adaptive motor responses (Bradley, 2009). In contrast, stimuli that are judged to be lower in arousal prompt substantially weaker levels of activation and are therefore less likely to prompt preferential attention.

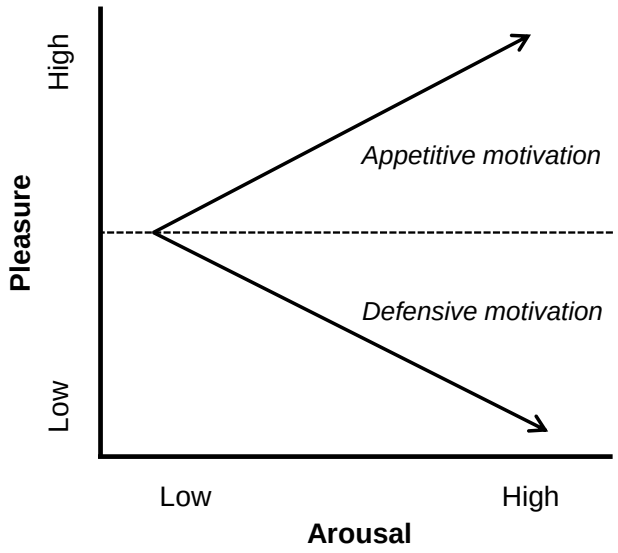

Figure 2.8. The motivational model of emotion. Adapted from Bradley (2009).

A two-dimensional structure of motivational significance has been supported by studies that have asked participants to rate samples of affective pictures according to arousal and valence. When plotted in Cartesian space, participants' judgments form two distinct slopes (Figure 2.8), with high arousing threatening and pleasant pictures corresponding to heightened activation of the defensive and appetitive systems, respectively (Bradley, 2009; Bradley, Codispoti, Cuthbert et al., 2001; Lang, Bradley, & Cuthbert, 1999). Ratings of arousal have also been found to vary systematically with physiological indices associated with activation of the appetitive and defensive motivational systems. For example, Bradley, Codispoti, Cuthbert et al. (2001) presented participants with photographic pictures of varying valence and arousal, while affective responses were measured via subjective judgements and physiological indices of autonomic activity. Participants' ratings of arousal were found to be positively associated with increases in skin conductance, independent of valence. Moreover, greater cardiac deceleration was observed in response to high arousing pleasant and aversive pictures relative to neutral pictures. In addition to

indexing the degree of motivational significance, increased skin conductance and HR deceleration serve as physiological markers of the orienting response (Bradley, 2009; Frith & Allen, 1983; Graham, 1979; Graham & Clifton, 1966). Given that autonomic changes indicative of orienting were observed for high arousing stimuli, irrespective of valence, the findings reported by Bradley, Codispoti, Cuthbert et al. (2001) suggest that stimulus arousal may underlie the allocation of attention. Supporting this interpretation, functional imaging studies have revealed correlations between changes in electrodermal activity and activation of the amygdala while participants viewed affective pictures (Hoffman, Gothard, Schmid, & Logothetis, 2007; Liberzon et al., 2000; Williams et al., 2001).

Chapter Summary

Although several models have been proposed to explain how affective stimuli influence the allocation of attention, these frameworks make differing predictions about (i) whether attentional prioritisation is sensitive to stimulus valence or arousal; (ii) the role of anxiety; and (iii) the influence of top-down, endogenous processes. Most of the models are predicated on the assumption that some form of valence evaluation mechanism allocates attention to stimuli that are reflective of biologically-prepared threats or which have learned associations with aversive outcomes (Beck & Clark, 1997; Clark & Beck, 2010; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Öhman, 1996; Öhman & Mineka, 2001; Whalen et al., 1998; Williams et al., 1988, 1997). Further, analysis of stimulus valence is presumed to reflect preattentive processes mediated by the amygdala (Carlson et al., 2009; LeDoux, 1995; Mogg & Bradley, 1998; Öhman, 2005; Öhman & Mineka, 2001; Öhman & Wiens, 2004; Whalen et al., 1998; Williams et al., 1988, 1997). Rather than assuming that attention is categorically biased towards negatively valenced

material, the motivational model of emotion predicts that both threatening *and* appetitive stimuli can attract preferential attention if they are relevant to current motivational needs (Bradley & Lang, 2007; Lang et al., 1997, 1998). From this standpoint, the key determinant of attentional orienting is arousal, which corresponds to the motivational relevance of a stimulus.

The models described also differ with respect to the role of anxiety. The two-stage model (Williams et al., 1988, 1997) assumes that the allocation of attention to threatening stimuli is moderated on the basis of trait anxiety, with enhanced attention to threat in high trait anxious individuals and avoidance of threat in low trait anxious individuals. The cognitive-motivational model (Mogg & Bradley, 1998) and the evolved fear module (Öhman, 1996; Öhman & Mineka, 2001), however, acknowledge that attention to intensely threatening stimuli is of adaptive importance. These models assume that even low anxious individuals will attend to stimuli that exceed some threat severity threshold. In particular, biologically-prepared stimuli that signal phylogenetic threats to survival are predicted to attract attention in all individuals (Öhman & Mineka, 2001). The motivational significance model (Lang et al., 1997, 1998) also attributes attentional prioritisation to innate processes that promote survival and propagation of the species (Bradley, 2009). Whereas high trait anxiety is considered to reflect hypersensitivity of the defensive motivational system to potential threats, transient increases in arousal may reflect activation of either defensive or appetitive circuitry in response to motivationally significant stimuli, irrespective of trait anxiety (Lang et al., 1998). Assuming that the degree of arousal elicited by a stimulus corresponds to its motivational significance, the physiological and cognitive responses that characterise state anxiety may occur on the basis of

current motivational needs and the presence of stimuli within the environment that are relevant to those needs.

Finally, while all of the models posit some form of threat detection mechanism, they vary with regards to the role of top-down processes. Both the cognitive-motivational model (Mogg & Bradley, 1998) and the two-stage model (Williams et al., 1988, 1997) propose that a resource allocation mechanism underlies the deployment of attentional resources, which operates automatically and is impervious to volitional effort. In contrast, the information processing model (Beck & Clark, 1997; Clark & Beck, 2010) assumes that threatening stimuli initiate consciously-mediated evaluations, which can delay attentional disengagement during strategic stages of processing. This assumption implies that endogenous allocation of attention is influenced by potentially threatening stimuli, especially in high anxious individuals. In non-anxious individuals, Mathews and Mackintosh (1998) claim that endogenously-mediated processes may operate to inhibit the allocation of attention to threatening stimuli in the service of preserving performance on current tasks. In other words, attentional control mechanisms can regulate the allocation of attention on the basis of cognitive goals and contextual demands. Whether attentional orienting to affective stimuli is sensitive to top-down attentional control or purely automatic, and therefore resistant to volitional efforts, has important implications. Most notably, the capacity to exert control over the allocation of attention may distinguish non-anxious individuals from those who are at risk of developing an anxiety-related disorder (Cisler & Koster, 2010; Derryberry & Reed, 2002).

CHAPTER III

EMPIRICAL EVIDENCE

Numerous experimental paradigms have yielded converging evidence of attentional biases towards affective stimuli. A commonality of these tasks is that attentional processes are inferred from reaction times (RTs), with comparisons drawn between responses to affective and neutral stimuli. The paradigms differ, however, with regards to the inferences that can be drawn about the mechanisms underlying biased attention. In the following chapter, the most commonly employed methodologies are discussed, including the key empirical findings they have yielded and their respective limitations.

Experimental Paradigms

Visual Search Task

Of all the paradigms reviewed in this chapter, the visual search task has been the most frequently employed to investigate attentional biases toward affectively valenced material in the general population (Yiend, 2010). In a typical version of the task, participants are shown matrices of stimuli and are instructed to detect the presence of a discrepant target stimulus embedded amongst an array of distracters. On some trials, an emotionally valenced target is embedded within an array of neutral or discordantly valenced stimuli, with detection latencies considered to reflect the speed with which attention is drawn to the affective stimulus (Cisler & Koster, 2010; Öhman, Flykt et al., 2001; Yiend, 2010). During other trials, participants are required to detect a neutral or affectively discordant target amongst an array of emotionally valenced stimuli. Response latencies on these trials are considered to index the degree to which valenced distractors hold attention, thereby

delaying detection of the target (Cisler & Koster, 2010; Miltner, Krieschel, Hecht, Trippe, & Weiss, 2004; Öhman, Flykt et al., 2001; Yiend, 2010).

In a visual search study by Fox et al. (2000), nonselect participants were faster at detecting discrepant faces displaying an angry expression amongst an array of neutral distractor faces compared to when they were required to detect a discrepant happy face. Results also revealed slower response latencies for detecting the absence of a discrepant neutral face in matrices comprised entirely of angry faces compared to matrices containing only happy faces. Findings of an "anger superiority effect" suggest that threatening faces are detected faster and engage attention longer than happy faces (Fox et al., 2000). In other studies employing the visual search task, however, attentional capture effects have also been observed for non-threatening faces, including happy and sad facial expressions, relative to neutral faces (Frischen, Eastwood, & Smilek, 2008; Juth, Lundqvist, Karlsson, & Öhman, 2005; Williams, Moss, Bradshaw, & Mattingley, 2005). Employing photographic faces, Juth et al. (2005) reported evidence of a "happiness superiority effect," with faster detection of happy expressions relative to angry and fearful expressions. Although these findings suggest that happy faces can also yield preferential attention, emotive facial expressions are likely to vary in the speed with which they are detected and the extent to which they hold attention, depending on their motivational relevance.

Enhanced attentional capture of biologically-prepared threat stimuli has also been demonstrated using the visual search task. In a study by Öhman, Flykt et al. (2001), nonselect participants were faster at detecting pictures of snakes and spiders embedded within matrices of flowers and mushrooms relative to detecting neutral targets. This finding suggests that the presence of threatening features can facilitate attentional engagement and is consistent with the assumptions of Öhman and

Mineka's (2001) evolved fear module. In another study, Lipp and Waters (2007) observed slower response latencies for detecting neutral target animals (i.e., fish and birds) included in arrays of threat-relevant animals (i.e., snakes and spiders) compared to arrays comprised of unpleasant, but non-threatening, animals (i.e., lizards and cockroaches). This result demonstrates that certain stimuli attract and hold attention on account of their resemblance to phylogenetic threats, lending further support to the evolved fear module. Providing evidence of enhanced detection of biologically-prepared appetitive stimuli, Nummenmaa, Hietanen, Calvo, and Hyona (2011) observed faster RTs for detecting pictures of food embedded within matrices of non-food distractors in comparison to detecting discrepant non-food targets. Consistent with motivational significance theory (Bradley & Lang, 2007; Lang et al., 1997, 1998), these data suggest that spatial attention is also biased toward stimuli that signal opportunities for satisfying basic primordial needs, such as nourishment. Providing further evidence that attention is oriented on the basis of motivation al significance, rather than valence, De Oca and Black (2013) observed faster detection of threatening *and* pleasant target pictures embedded in matrices of neutral distractors compared to neutral targets.

Although studies employing the visual search task provide strong evidence that attentional allocation is biased by emotional stimuli, the affective properties that attract attention remains unclear. Of particular importance, stimuli commonly employed in these studies are likely to vary in the degree of arousal they elicit, in addition to valence. For example, angry faces have shown to be not only more threatening than sad or happy faces, but also more arousing (Johnsen, Thayer, & Hugdahl, 1995; Schupp, Cuthbert et al., 2004). Pictures of snakes and spiders have also obtained higher arousal ratings compared to pictures of flowers and mushrooms

(Soares, Esteves, Lundqvist, & Öhman, 2009; Thomas & LaBar, 2008). It is therefore unclear whether attentional biases observed using the visual search paradigm are mediated by stimulus valence or arousal. In contradiction to a threat-superiority effect, recent visual search studies have found that search efficiency is better predicted by arousal than valence (Lundqvist, Bruce, & Öhman, 2015).

Another concern regarding the visual search task is that the reliability of the anger and happiness superiority effects appears to vary with the type of stimuli employed. Whereas the anger superiority effect has been consistently observed when matrices are comprised of simplistic schematic faces (Öhman, Lundqvist et al., 2001), the happiness superiority effect is more reliably observed when photographs of facial expressions are employed (Becker, Anderson, Mortensen, Neufeld, & Neel, 2011; Juth et al., 2005; Williams et al., 2005). Although schematic faces may minimise low-level visual confounds, they lack ecological validity. In contrast, photographic pictures are more realistic and analogous to real life encounters.

A key tenet of the models that attempt to explain attentional biases is that rapid detection of threatening stimuli occurs automatically (Beck & Clark, 1997; Clark & Beck, 2010; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Öhman, 1996; Öhman & Mineka, 2001; Williams et al., 1988, 1997). Supporting this assumption, Öhman, Flykt et al. (2001) found that response latencies for detecting snakes and spiders were uninfluenced by the number of distractors included in the arrays (3 vs. 8). These data suggest that the detection of threatening stimuli is achieved by parallel, automatic processes. In other studies that have systematically manipulated the array size, however, the search for negatively valenced stimuli appears to be exhaustive, as demonstrated by an increase in detection times as a function of the number of distractors (Eastwood, Smilek, & Merikle, 2001; Fox et

al., 2000). Such data suggest that detection of threat-relevant stimuli during the visual search task places demands on consciously-mediated processes. Given these diverging results, it is unclear whether visual searches for emotionally valenced stimuli are reflective of automatic or controlled processes, or both. Because valenced stimuli are typically relevant to the search goal, top-down influences, including consciously-mediated search strategies, are also likely to influence participants' performance on the task, potentially overshadowing automatic attentional biases (Frischen et al., 2008).

Summary. In studies that have employed the visual search task with nonselect samples, detection latencies have reliably indicated that spatial attention preferences emotive faces (Fox et al., 2000; Frischen et al., 2008; Juth et al., 2005; Williams et al., 2005), biologically-prepared threats (Lipp & Waters, 2007; Öhman, Flykt et al., 2001), and appetitive cues (De Oca & Black, 2013; Nummenmaa et al., 2011). Although the effect of emotional stimuli on visual search efficiency is frequently attributed to valence and interpreted as a threat-superiority bias, the influence of stimulus arousal has seldom been accounted for and may offer an alternative explanation of visual search data (Lundqvist, Juth, & Öhman, 2014). The visual search task, however, has limited utility in explaining how the allocation of attention to affective stimuli varies along the time-course of information processing. Manipulating the size of the search arrays has produced conflicting findings regarding whether detection of affective targets reflects an automatic or controlled process (Eastwood et al., 2001; Fox et al., 2000; Öhman, Flykt et al., 2001). Moreover, because the visual search task requires stimuli to remain visible until participants have indicated the presence or absence of the target, the time-course of effects observed on the visual search paradigm cannot determined.

Emotional Stroop Task

The Stroop paradigm has been extensively used to demonstrate how some stimulus features can attract automatic attention and interfere with top-down, controlled processes (MacLeod, 1991, 1992). In the classic Stroop task, colour words are presented in font colours that are either congruent (e.g., the word blue presented in blue font) or incongruent (e.g., the word blue presented in red font) with the semantic properties of the item. Participants are required to name the colour in which the word is presented, while disregarding the word's meaning. RTs for responding to congruent presentations are typically faster than RTs obtained for incongruent presentations. One explanation for this effect is that word reading occurs automatically and draws attention to the word's semantic content, thereby interfering with naming the font colour. A variation of the classic paradigm, the emotional Stroop task examines attention toward affectively valenced words. Positive and negative words are presented in varying colours and participants are instructed to name the font colour of the item, while disregarding its affective meaning. Attentional biases are inferred by differential colour naming latencies for affective words compared to neutral words.

The emotional Stroop paradigm has yielded robust effects, demonstrating biased processing of affectively valenced information (Phaf & Kan, 2007). Pratto and John (1991) administered the emotional Stroop task to a nonselect sample and observed slower colour naming for negative trait words (e.g., hostile) relative to positive trait words (e.g., honest). These findings were replicated by Wentura, Rothermund, and Bak (2000), supporting the assumption of a categorical bias toward negative stimuli in the general population. In other studies employing the emotional Stroop task, slower response latencies for negatively valenced words have been

consistently reported in clinically anxious samples (Martin, Williams, & Clark, 1991; Mathews & MacLeod, 1985; Mogg, Mathews, & Weinman, 1989; Owens, Asmundson, Hadjistavropoulos, & Owens, 2004), in addition to non-clinical samples comprised of high trait anxious participants (Edwards, Burt, & Lipp, 2010a, 2010b; Fox, 1993; Mogg, Mathews, Bird, & Macgregor-Morris, 1990; Richards & Millwood, 1989; Rutherford et al., 2004). A limitation in interpreting these results in terms of a threat-superiority effect, however, resides in the fact that the threat and positive words were not matched on arousal. If the threat words were more arousing, then these data may simply reflect the effects of arousal, rather than threat *per se*.

Although a bias for negatively valenced words has been supported by numerous studies employing the emotional Stroop paradigm, there is also evidence of Stroop interference for positive words. Rutherford et al. (2004) observed slower responding on trials employing negative *and* positive words relative to neutral words for participants who reported heightened state anxiety, providing evidence of a general bias toward affectively valenced stimuli. Strauss and Allen (2006) also observed a bias toward high arousing, positive words, which was associated with self-reported positive affect. These findings demonstrate that interference effects observed on the emotional Stroop task are not restricted to negative information and may be mediated by current mood and affective states (Strauss & Allen, 2006). Moreover, studies that have matched stimuli in terms of subjective ratings of arousal have found that high arousing negative and positive words both elicit interference, suggesting that the effects of affective stimuli observed on the emotional Stroop task may be attributable to arousal as opposed to valence (Dresler et al., 2009; Pratto, 1994). In further support of a motivational account of attentional biases, slower response latencies have also been observed for naming the colour of food-related

words in participants who fasted for a period of 24 hours (Channon & Hayward, 1990; Lavy & van den Hout, 1993). Moreover, the degree of colour naming interference was found to be positively correlated with self-reported feelings of hunger, suggesting that biases observed on the emotional Stroop task might be associated with motivational states.

A key limitation of the emotional Stroop task is that the stimuli employed are typically restricted to words. As argued by Phaf and Kan (2007), the visual appearance of words varies across languages, despite having the same meaning and emotional relevance. Consequently, affective words are not naturalistic exemplars of phylogenetic stimuli and are therefore unlikely to activate the direct thalamic pathway proposed by LeDoux (1996). Due to the task's reliance on word stimuli, the emotional Stroop task is less than ideal for examining attentional biases towards stimuli that have gained significance through our evolutionary history. Furthermore, although findings from the emotional Stroop have typically been interpreted as reflecting an automatic bias toward emotionally-provocative information, the precise nature of this effect remains unclear. In masked versions of the emotional Stroop task that restrict conscious awareness of the stimuli, interference effects are either absent (Phaf & Kan, 2007) or smaller (Bar-Haim et al., 2007) compared to those found under supraliminal exposure conditions. During unmasked versions of the emotional Stroop task, word stimuli remain visible until the participant has made their response. Because the duration of stimulus exposure cannot be manipulated, supraliminal versions of the task are unable to examine the precise time-course of attentional processing. This limitation is particularly problematic given that the components of attentional bias have been shown to operate during distinct temporal

stages of processing (Koster, Crombez, Verschuere, Vanvolsem, & De Houwer, 2007).

Conflicting interpretations of what the emotional Stroop effect actually reflects is an ongoing source of contention, further limiting the interpretative utility of the task (Yiend, 2010). A meta-analysis by Phaf and Kan (2007) revealed that interference effects are strongest under conditions employing a blocked format, as opposed to randomised trials, suggesting that the emotional Stroop effect may be partially due to cumulative exposure to stimuli of a particular valence. Moreover, McKenna and Sharma (2004) observed that slower colour naming latencies only occurred for trials following threatening words and not the immediate trial. These findings suggest that results derived from the emotional Stroop task may be better explained by a process that is slow to operate, as opposed to automatic. One explanation is that participants experienced difficulty disengaging their attention from emotionally evocative content, thereby interfering with performance on the subsequent trial (McKenna & Sharma, 2004). An alternative interpretation offered by De Ruiter and Brosschot (1994) suggests that interference effects observed on the emotional Stroop task may reflect efforts to avoid evocative stimuli by suppressing their semantic content, rather than attentional capture. Others have suggested that the effects may be unrelated to selective attention altogether, and instead reflect generic response slowing (Algom, Chajut, & Lev, 2004). Given the discrepant interpretations inherent with the task, and the inability to determine the precise time-course of effects, the emotional Stroop paradigm is unable to effectively discern which components of visual attention are influenced by affective stimuli.

Summary. Research employing the emotional Stroop task has revealed a robust effect of negatively valenced words on colour naming latencies, which has

been interpreted in terms of a categorical bias toward negative stimuli (Edwards et al., 2010a, 2010b; Fox, 1993; Martin et al., 1991; Mathews & MacLeod, 1985; Mogg et al., 1990; Mogg et al., 1989; Owens et al., 2004; Pratto & John, 1991; Richards & Millwood, 1989; Rutherford et al., 2004; Wentura et al., 2000). In emotional Stroop studies that have included positively valenced words, however, a general bias for valenced stimuli has been observed, with colour naming delayed for both positive and negative words compared to neutral words (Rutherford et al., 2004; Strauss & Allen, 2006). Consistent with the motivational model of emotion (Lang et al., 1997, 1998), slowed colour naming latencies have also been reported for appetitive stimuli (i.e., food words) during heightened motivational states (i.e., hunger), indicating that interference on the emotional Stroop task may operate according to the motivational significance of the stimuli (Channon & Hayward, 1990; Lavy & Van den Hout, 1993).

Like the visual search paradigm, the emotional Stroop task has limited utility in determining the time-course of the effects of valence and arousal on attentional processes. A further limitation is that the emotional Stroop task is typically limited to words, which despite their emotional relevance, lack biologically-relevant features (Phaf & Kan, 2007). Interpretative limitations also prevent firm conclusions about the nature of emotional Stroop effects. Whether delayed colour naming latencies are related to the allocation of attention (McKenna & Sharma, 2004; Phaf & Kan, 2007), effortful avoidance (De Ruiter & Brosschot, 1994), or non-attentional processes, such as general response slowing (Algom et al., 2004), remains unclear.

Dot-Probe Task

To address the interpretative limitations of the emotional Stroop task, MacLeod, Mathews, and Tata (1986) developed the dot-probe paradigm. In this task,

two stimuli are presented concurrently in opposing spatial locations. Typically, one stimulus is affectively valenced and the other neutral. Following the offset of the stimuli, a probe appears in the location previously occupied by either the valenced stimulus or neutral stimulus. Participants are required to respond to the probe as quickly as possible by either indicating its location (e.g., left or right) or differentiating between two perceptually distinct probes (e.g., X or O). Given that responses to attended locations occur faster relative to unattended locations, response latencies for the probes provide an index of the allocation of spatial attention (MacLeod et al., 1986). An advantage of the dot-probe task over related paradigms (e.g., visual search and emotional Stroop) is that participants respond to a probe in the absence of any emotional information. This procedure helps to ensure process-pure measures by reducing the influence of response bias and non-attentional interference, thereby yielding a clearer measure of the allocation of spatial attention (Yiend, 2010). The structure of the task also allows for the stimulus onset asynchrony (SOA) between the stimuli and the probe to be manipulated, thereby allowing researchers to examine the time-course of attentional processing.

Lipp and Derakshan (2005) employed the dot-probe task to examine attentional biases for threat-relevant stimuli relative to neutral stimuli in a nonselect, student sample. Consistent with the assumptions of the evolved fear module (Öhman, 1996; Öhman & Mineka, 2001), RTs were faster when probes appeared in the same location as pictures of snakes and spiders compared to pictures of mushrooms and flowers. Threat biases did not correlate with self-reported state and trait anxiety, suggesting that biologically-prepared threat stimuli can attract attentional biases in nonclinical populations, irrespective of anxious affect. Providing further evidence that attention is more readily captured by threatening material,

nonselect participants have been shown to respond faster to probes located in the same location as intensely threatening pictures depicting mutilated bodies and violence compared to probes replacing pictures of household objects (Koster, Crombez, Verschuere, & De Houwer, 2004). In a follow-up study that compared high and low anxious participants, faster detection latencies were observed for probes appearing in the same location as intensely threatening pictures, independent of anxiety (Koster, Crombez, Verschuere, & De Houwer, 2006). In contrast, only high trait anxious participants were faster to detect probes that replaced moderately threatening pictures. These findings support the assumption that highly threatening stimuli attract preferential attention in all individuals, irrespective of anxiety, whereas biases for mild to moderately threatening stimuli may be specific to anxious individuals (Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Öhman, 1996; Öhman & Mineka, 2001).

Although several dot-probe studies have reported evidence of a threat-superiority effect on the basis of comparisons with neutral stimuli (Koster, Crombez, Verschuere et al., 2004; Koster, Crombez, Verschuere, & De Houwer, 2006; Lipp & Derakshan, 2005), positively valenced pictures are rarely included, rendering it impossible to draw conclusions about the relative influence of valence and arousal on spatial attention. Providing evidence that attention during the dot-probe task also preferences appetitive stimuli, Brosch, Sander, and Scherer (2007) observed faster responding to probes that appeared in the same location as faces of human infants relative to faces of adults. Given that nurturance of human offspring is of high adaptive importance, increasing the likelihood that one's genes will be propagated to successive generations, pictures of babies are assumed to activate the appetitive motivational system (Lang, 2010; Pool et al., 2016). In a subsequent experiment,

Brosch, Sander, Pourtois, and Scherer (2008) observed comparable detection latencies for probes that were preceded by pictures of babies and angry adult faces, which were faster than RTs to probes replacing neutral facial expressions. These results were interpreted in terms of automatic attention to biologically-relevant stimuli. In another dot-probe study, participants who fasted for an average of 15 hours demonstrated an attentional bias toward food-related words, which was positively associated with ratings of hunger (Mogg, Bradley, Hyare, & Lee, 1998). These results were not found for non-fasting participants, supporting predictions that appetitive motivational states, such as hunger, can promote preferential allocation of attention to biologically-prepared, appetitive stimuli. Rather than supporting a threat-superiority bias, current findings suggest that spatial attention preferences both threatening and appetitive stimuli that are of motivational significance to an individual and the species.

Results derived from the dot-probe task also demonstrate that the allocation of attention to affectively valenced stimuli varies across time. Cooper and Langton (2006) presented nonselect participants with angry-neutral and happy-neutral face pairs. When the SOA between the faces and the probe was 100 ms, faster responses were observed for probes appearing in the location previously occupied by angry faces compared to probes replacing neutral faces, suggesting that attention preferences threatening stimuli during early stages of processing. When the SOA was increased to 500 ms, however, responses were slower for probes appearing in the location of angry faces, indicating a bias away from threatening stimuli during later stages of processing. In contrast, faster responding was observed for probes replacing happy faces relative to neutral faces in the longer exposure condition. This

finding suggests that positively valenced stimuli may also attract preferential attention, but along a slower time-course relative to threatening stimuli.

Although the dot-probe task has advantages over the visual search and emotional Stroop paradigms, the nature of the task causes difficulties in determining which components of spatial attention are affected by emotional stimuli (Yiend, 2010). Each trial involves the presentation of two stimuli, one of which is neutral and the other threatening or appetitive. On trials where the probe replaces a threatening or appetitive picture, RTs may be accelerated due to facilitated engagement of the affective content. An equally plausible explanation, however, is that effects on dot-probe task are a result of delayed disengagement. Specifically, when the probe replaces a neutral picture, responses may be slowed due to delayed shifts of attention away from the affective pictures. Because two stimuli are presented simultaneously on each trial of the dot-probe, it is impossible to discern whether speeded RTs reflect the effects of affective stimuli on attentional engagement, disengagement, or both (Fox, Russo, Bowles, & Dutton, 2001; Koster, Crombez, Verschuere et al., 2004; Yiend, 2010).

Summary. In contrast to the visual search and emotional Stroop paradigms, the dot-probe task allows for clearer inferences regarding the effects of emotional stimuli on spatial attention, including the time-course of attentional allocation (Yiend, 2010). In dot-probe studies conducted with nonselect participants, attention has been found to preference pictures of biologically-prepared threats, with faster responding to probes appearing in the same location as fear-relevant animals, human attack scenes, and mutilated bodies compared to non-threatening stimuli (Koster, Crombez, Verschuere et al., 2004; Lipp & Derakshan, 2005). In the comparatively few dot-probe studies that have included appetitive stimuli, pictures of human infants

have also been found to attract attention (Brosch et al., 2008; Brosch et al., 2007), as have food-related pictures following a period of fasting (Mogg et al., 1998). Considered together, evidence derived from the dot-probe task indicates that attention is biased towards both threatening and appetitive stimuli that are of biological relevance, consistent with motivational significance theory (Lang et al., 1997, 1998). In studies that have manipulated the SOA between the cues and probe, the allocation of attention appears to favour threatening stimuli during early stages of processing and appetitive stimuli during later stages (Cooper & Langton, 2006). Despite yielding evidence of preferential attention for motivationally significant stimuli, it is unclear whether these types of cues capture attention more readily or hold attention for longer relative to neutral cues (Fox et al., 2001; Koster, Crombez, Verschuere et al., 2004; Yiend, 2010). That is, the dot-probe task cannot delineate whether the observed effects are due to facilitated attentional engagement, difficulty disengaging attention, or both.

Spatial Cueing Task

Developed from Posner's (1980) exogenous cueing paradigm, the spatial cueing task (SCT) is capable of disambiguating the effects of affective stimuli on the distinct components of spatial attention. That is, results derived from the SCT can yield information regarding facilitated attentional engagement, delayed disengagement, and IoR. In a typical version of the task, participants are required to attend to a central fixation point presented between two peripheral placeholder boxes. On each trial, a single picture appears in one of the boxes and is followed by a probe. Participants are required to respond to the probe as quickly as possible, either by indicating its location or by discriminating between two perceptually distinct probes. On valid trials, the probe appears in the same location as the cue, with

response latencies interpreted as an index of the speed of attentional engagement toward the cued location. On invalid trials, the probe appears in the opposite periphery to the cue. Because participants must shift their attention away from the cued location in order to detect the probe, RTs for invalid trials are assumed to index the speed of disengagement. Faster RTs are typically observed for validly cued probes, a phenomenon referred to as the "cue validity effect." By preceding probes with cues that vary in affective valence, it is possible to examine whether the cue validity effect is augmented by emotional content. Facilitated engagement is evident if responses to validly cued probes are faster when preceded by a valenced or motivationally significant cue, as opposed to a neutral cue. Difficulty disengaging attention is demonstrated by slower response latencies for invalidly cued probes that are preceded by an emotive cue compared to a neutral cue.

Fox et al. (2001) employed the SCT across a series of experiments, using affective words, schematic facial expressions, and photographs of emotive faces as cues. On invalid trials, both anxious and non-anxious participants were slower to indicate the location of probes (left vs. right) following 100 ms of exposure to threat-related words relative to neutral or positive words (Experiment 1). These results demonstrate that threatening stimuli can hold attention, resulting in delayed disengagement from the cued location. No evidence of facilitated attentional engagement was observed, with RTs for validly cued probes being uninfluenced by whether the preceding cue was a threatening, positive, or neutral word. In a second experiment, schematic faces served as cues and were exposed for either 100 ms or 250 ms. Consistent with the previous experiment, when invalid cues were presented for 100 ms there was evidence of delayed disengagement from angry faces relative to happy and neutral faces, which was not qualified by anxiety group. When the

duration of cue exposure was extended to 250 ms, however, only the high state anxious participants were slower to disengage their attention from the threatening faces. The pattern of findings reported by Fox et al. (2001) suggests that (i) threatening stimuli hold attention, thereby slowing attentional disengagement, and (ii) delayed disengagement from threat occurs for all individuals, but terminates faster those reporting low levels of anxiety.

A limitation of the study by Fox et al. (2001) is that the affective words and facial expressions used in these experiments may have lacked sufficient threat intensity or arousal to sustain biased attention in the low anxious participants. The cognitive-motivational model (Mogg & Bradley, 1998) predicts that the degree of threat posed by a stimulus, as assessed by the VES, determines the extent to which attentional processes are biased in non-anxious individuals. Due to a higher threshold for threat evaluation in individuals reporting low levels of anxiety, only stimuli tagged as highly threatening are assumed to attract biased attentional processing. If stimulus arousal determines threat intensity for negatively valenced stimuli, then attentional biases may be maintained longer in the presence of highly arousing, threatening stimuli, even in non-anxious individuals. A second limitation of the findings reported by Fox et al. (2001) is that the negative and positive stimuli included in their experiments were not explicitly matched on arousal. This leaves open the possibility that the threatening words and angry facial expressions held attention longer on the basis of motivational significance, as indexed by arousal, rather than valence.

In spatial cueing studies that have incorporated fear-conditioning procedures, threat-relevant stimuli have shown to facilitate attentional engagement (Koster, Crombez, Van Damme et al., 2004, 2005; Massar, Mol, Kenemans, & Baas, 2011;

Van Damme, Crombez, Hermans, Koster, & Eccleston, 2006). On valid trials, participants responded faster to probes preceded by stimuli associated with aversive stimulation, including electric shock and loud noises, relative to stimuli not associated with noxious events. These studies also found evidence of delayed disengagement, with slowed responding for probes appearing in the opposite location as the conditioned stimuli. Although cues of imminent threat appear to facilitate attentional engagement and hold attention longer relative to neutral stimuli, a spatial cueing study that employed appetitive conditioning procedures found facilitated engagement of stimuli associated with the odour of chocolate, indicating that subjects also rapidly orient to appetitive stimuli (Pool, Brosch, Delplanque, & Sander, 2014). In studies that combined Pavlovian conditioning procedures with the SCT, stimuli were simplistic, geometric shapes that lacked naturalistic representation of biologically-prepared threats and appetitive opportunities. Although innocuous stimuli, such as shapes, may acquire motivational relevance due to learned associations with aversive or appetitive outcomes, a fundamental assumption of the evolved fear module (Öhman, 1996; Öhman & Mineka, 2001) is that humans are born with innate feature detectors which respond to threats faced by our evolutionary ancestors. As such, facilitated engagement of affective stimuli is expected to occur even in the absence of learned associations.

Employing pictures from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999, 2005) as cues, Yiend and Mathews (2001; Experiment 2) reported evidence of delayed disengagement from threat in high anxious participants, with RTs on invalid trials slowed by pictures of human mutilations, attack scenes, and dangerous animals compared to non-threatening pictures that depicted landscapes and domestic scenes. In contrast, there was no

difference in response latencies following threatening and nonthreatening pictures for low anxious participants, suggesting that spatial attention was unaffected by valence. In a study by Waters et al. (2007), a *negative* cue validity effect was observed following 500 ms of cue exposure, with slower responding on valid trials than invalid trials. Consistent with IoR, a negative cue validity effect indicates that attention was directed away from the cued location at the time of probe-onset. For low anxious participants, the negative cue validity effect was strongest when the probes followed threatening pictures compared to pleasant and neutral pictures. This finding suggests that spatial attention is directed *away* from threatening stimuli in low anxious individuals, perhaps as a means of regulating emotional reactivity by inhibiting excessive processing of aversive material (Waters et al, 2007). Further evidence of attentional avoidance of threat in low anxious participants has been reported by Sagliano, Trojano et al. (2014), with slower detection latencies for validly cued probes preceded by threatening pictures compared to non-threatening pictures. These findings are consistent with predictions made by the two-stage model (Williams et al., 1988, 1997), such that low trait anxious individuals are more likely to direct attentional resources away from a stimulus as the degree of threat increases. In addition to attentional avoidance, Sagliano, Trojano et al. (2014) found that responses following threatening pictures were also slower on invalid trials, consistent with delayed disengagement from threat.

Although a number of spatial cueing studies suggest that attentional biases in non-anxious individuals may be best defined in terms of delayed disengagement and avoidance of threat (Fox et al., 2001; Sagliano, Trojano et al., 2014; Waters et al., 2007), the allocation of attention to affectively valenced stimuli may operate along a faster time-course in participants reporting lower levels of anxiety. In a series of

experiments conducted by Koster, Crombez et al. (2007), threatening scenes of varying intensity were employed in a SCT administered to nonselect participants. When the pictures were presented for 100 ms, the valid trials revealed evidence of biased attentional engagement (experiments 1, 2, and 4). RTs were significantly faster following high threat cues compared to the neutral and low threat cues. This pattern was reversed for the invalid trials, with significantly slower RTs following high threat cues relative to the neutral cues (experiment 4). Supporting the notion that attentional biases operate earlier in non-anxious individuals, the findings reported by Koster, Crombez et al. (2007) suggest that during very early stages of information processing (i) the highly threatening pictures engaged participants' attention more readily, and (ii) held attention longer in comparison to less threatening and neutral pictures. This interpretation is consistent with models proposing that severely threatening stimuli attract biased attention irrespective of anxiety (Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Öhman, 1996; Öhman & Mineka, 2001). Despite demonstrating facilitated engagement and delayed disengagement for threatening stimuli in non-anxious participants, the study reported by Koster, Crombez et al. (2007) was limited by the fact that it did not include appetitive stimuli. Their data were therefore unable to confirm whether attention is categorically biased toward negatively valenced or threatening information, or whether these effects might operate for other types of motivationally significant stimuli, such as high arousing appetitive pictures. Indeed, direct comparisons of equivalently arousing threatening and appetitive pictures are notably scarce in studies employing the SCT.

Spatial cueing studies that have included positively valenced pictures have found that spatial attention is also augmented for stimuli that activate the appetitive

motivational system (Pool et al., 2016). In a study by Vogt et al. (2008), cues preceding the probes included pictures that contained either pleasant or aversive content. In addition to valence, the pictures were also categorised as low or high arousing on the basis of normative IAPS ratings (Lang et al., 1999, 2005). On invalid trials, participants were slower to respond when the probes followed high arousing cues relative to low arousing cues, reflecting delayed disengagement from the high arousing pictures. Moreover, this effect was independent of stimulus valence, providing strong evidence that difficulty disengaging attention from affective stimuli is dependent on stimulus arousal rather than threat value. In agreement with these findings, Sawada and Sato (2015) observed faster RTs on valid trials and slower RTs on invalid trials for probes that replaced both happy and angry faces compared to neutral faces. Moreover, faster response latencies on valid trials and slower responses on invalid trials were associated with higher ratings of stimulus arousal, whereas associations with ratings of valence were nonsignificant. These results provide strong evidence that facilitated engagement and delayed disengagement operate as a function of arousal.

In another spatial cueing study, participants who were primed to experience increased sexual arousal were slower to respond to invalidly cued probes preceded by pictures of attractive members of the opposite sex (Maner, Gailliot, Rouby, & Miller, 2007). This finding suggests that individuals are slower to disengage their attention away from possible mating-related cues, which may be associated with appetitive motivational states such as sexual arousal. Other studies have replicated the results reported by Maner, Gailliot, Rouby et al. (2007), with participants slower to shift their attention away from attractive, opposite-sex faces compared to neutral and unattractive faces (Koranyi & Rothermund, 2012; Sui & Liu, 2009). From an

evolutionary standpoint, physically attractive members of the opposite gender represent a potential mating opportunity and appear to be associated with activation of the appetitive motivational system (Bradley, Codispoti, Cuthbert et al., 2001; Maner, Gailliot, Rouby et al., 2007).

Summary. Because only a single picture is presented on each trial of the SCT, which may either cue the correct location of the probe (valid trials) or the opposite location (invalid trials), the paradigm offers greater specificity regarding the components of attention that are affected by emotionally valenced stimuli. The SCT has been most frequently employed to examine attention for threat, with response latencies on valid trials indicating facilitated engagement of intensely threatening pictures during early stages of processing (~ 100 ms; Koster, Crombez et al., 2007). Although there is also evidence of delayed disengagement from threat (Fox et al., 2001; Koster, Crombez, Van Damme et al., 2004; Koster, Verschuere et al., 2005; Massar et al., 2011; Sagliano, Trojano et al., 2014), spatial cueing studies that have examined attention for appetitive stimuli suggest that disengagement may be slowed as a function of stimulus arousal, as opposed to valence (Sawada & Sato, 2015; Vogt et al., 2008). Somewhat conflicting findings suggest that non-anxious participants direct attention away from threatening stimuli (Sagliano, Trojano et al., 2014; Waters et al., 2007), however, such avoidance may be limited to exposure conditions that correspond to later stages of processing. At this time, no spatial cueing studies could be located that have directly compared the allocation of attention to high arousing, threatening and appetitive stimuli while manipulating the exposure duration of the cues. Consequently, it remains unclear how the distinct components of spatial attention are affected by valence and arousal across the time-course of information processing.

General Limitations & Aims of the Thesis

Despite robust evidence that affectively valenced stimuli attract preferential processing, the stimulus dimensions that drive this phenomenon remain inconclusive. The nature of prioritised attention within the general population is also unclear, with the components of attentional bias being unreliably observed in non-anxious participants. The inconsistent findings are likely to reflect methodological differences across studies, particularly concerning the type of stimuli used, their duration of exposure, and relevance to task demands. Given that the majority of previous research has focused on attention for negatively valenced and threat-related material, the effects of appetitive stimuli on attentional processes remain relatively unexplored. From an evolutionary perspective, both appetitive and threatening cues have important implications for survival of the species, and therefore have greater motivational relevance compared with affectively neutral events (Derryberry & Rothbart, 1997). Previous studies, however, have either not included positively valenced stimuli or have neglected to match positive and negative stimuli on arousal. That is, some studies have compared high arousing negative stimuli with positive stimuli that are potentially less arousing, thereby confounding the effects of valence with arousal (e.g., Bradley, Mogg, & Millar, 2000; Fox et al., 2001; Lipp & Derakshan, 2005; Öhman, Flykt et al., 2001). Because threat-related stimuli also tend to be highly arousing, it remains unclear whether valence or arousal mediates the allocation of spatial attention to emotional stimuli.

Sampling characteristics may be another contributing factor for the lack of consistent findings in the existing literature. In many of the previous studies, low trait anxious participants were defined as those who scored in the bottom quartile or below the median on a trait anxiety measure (e.g., Fox et al., 2001; Fox et al., 2002;

Koster, Crombez, Verschuere, & De Houwer, 2006; Sagliano, Trojano et al., 2014; Waters et al., 2007; Yiend & Mathews, 2001). It can be argued that these participants represent a group of people with abnormally low levels of anxiety and are therefore not representative of the general population. Despite a large body of research investigating the influence of anxiety on attention for affective stimuli, there is a dearth of research examining how the affective dimensions of a stimulus influence attention in nonselect participants. If it is accepted that attentional biases are a product of Darwinian evolution, they should be observable irrespective of anxiety. The current thesis therefore aimed to contribute to the existing literature by investigating how attentional orienting is directed toward motivationally significant stimuli in individuals sampled from the general population, after controlling for individual differences in state and trait anxiety.

In accordance with motivational accounts of affective processing, an adaptive attentional system should prioritise high arousing appetitive stimuli, in addition to cues of potential threat. Supporting this claim, there is growing evidence that the allocation of spatial attention toward affectively valenced stimuli occurs as a function of arousal, not valence (Sawada & Sato, 2015; Schimmack, 2005; Vogt et al., 2008). Accordingly, the current thesis sought to investigate whether attentional biases commonly interpreted as increased vigilance toward negative or threat-related stimuli may be better explained in terms of motivational significance, with biases toward both high arousing threatening and appetitive stimuli that are symbolic of our evolutionary needs. To test the predictions made by the motivational model of emotion (Lang et al., 1997, 1998) against threat-specific models (Beck & Clark, 1997; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Öhman, 1996; Öhman & Mineka, 2001; Williams et al., 1988, 1997), a novel set of motivationally

significant stimuli was developed, which included threatening and appetitive pictures that varied in arousal. Across a series of experiments, participants completed a SCT to measure the allocation of spatial attention toward the motivationally significant pictures. This well-established task was selected over other paradigms because of its capacity to yield distinct indices of facilitated attentional engagement, delayed disengagement, and avoidance.

Another advantage of the SCT is that the time-course of attentional biases can be examined by systematically varying the exposure duration of the cues. On the basis of existing research, the components of attentional bias are thought to operate differentially over time (Cisler, Bacon, & Williams, 2009; Cisler & Koster, 2010). That is, the nature of attentional biases has been shown to vary as a function of the duration of stimulus exposure. Consistent with models that predict rapid detection of threat, evidence of facilitated attentional engagement toward highly threatening pictures in nonselect participants has been observed at brief exposure durations (i.e., ≤ 100 ms; Cisler & Koster, 2010; Koster, Crombez, Verschuere, Van Damme et al., 2006; Koster, Crombez et al., 2007). As the length of cue exposure increases, strategic processes are presumed to operate on attentional orienting, producing delayed disengagement and attentional avoidance at intermediate (100-500 ms) and long presentation durations (≥ 500 ms), respectively (Cisler & Koster, 2010; Koster, Crombez, Verschuere, Van Damme et al., 2006; Mogg, Philippot, & Bradley, 2004). To maximise the likelihood of observing facilitated engagement, delayed disengagement, and avoidance effects, these previous findings informed the cue durations employed in the current research.

Surprisingly, few, if any, spatial cueing studies have examined how attention is allocated to both threatening and appetitive stimuli, while manipulating the length

of cue exposure. By systematically examining the effects of stimulus valence and arousal on spatial orienting, the current research aimed to yield valuable insights into how visual attention is augmented by motivationally significant stimuli along the time-course of information processing.

CHAPTER IV

STUDY 1

The first study was designed to validate a novel set of affective pictures to be used during the subsequent spatial cueing experiments. Previous studies examining the effects of valence and arousal on attention have often adopted heterogeneous stimulus categories that are represented by a variety of picture contents. Threatening stimuli are often represented by pictures of human mutilations, attack scenes, and dangerous animals (e.g., Koster, Crombez, Verschuere, Van Damme et al., 2006; Koster, Crombez et al., 2007; Waters et al., 2007), whereas pleasant stimuli are frequently depicted by pictures that lack the same degree of evolutionary significance. For example, several studies have included pictures of extreme sports, scenic landscapes, and non-threatening animals (e.g., kittens and puppies; Buodo, Sarlo, & Palomba, 2002; Feng et al., 2012; Matlow, Gard, & Berg, 2012; Schimmack, 2005; Vogt et al., 2008). Such pictures are devoid of any obvious relevance to survival and are therefore unlikely to activate appetitive motivational pathways.

Accepted as being of evolutionary importance, pictures of human faces have been frequently employed to examine attentional orienting for different emotional expressions (Fox et al., 2000; Fox et al., 2001; Fox et al., 2002; Koster, Verschuere et al., 2007; Öhman, 2002; Putman et al., 2004; Tipples, 2006). Smiling and elated faces, however, are unlikely to be sufficiently arousing to elicit cognitive biases, especially when compared with angry or fearful faces (Johnsen et al., 1995; Schupp, Cuthbert et al., 2004). Other studies have relied on pictures of food to represent appetitive stimuli (e.g., Johansson, Ghaderi, & Andersson, 2004; Leland & Pineda, 2006; Nummenmaa et al., 2011; Tapper, Pothos, & Lawrence, 2010). Although

food-related cues are symbolic of opportunities for nourishment, the motivation significance of these stimuli is largely dependent on a participant's state of hunger (Buckhout & Grace, 1966; Drobes et al., 2001; Tapper et al., 2010). Consequently, attentional biases to pictures of food tend to be attenuated for satiated participants, thereby underestimating attentional preferences for appetitive stimuli (Pool et al., 2016).

Another limitation with respect to the stimuli employed in previous studies is that affectively neutral stimuli have been frequently represented by pictures that depict inanimate objects, such as household items or innocuous plants and fauna (e.g., flowers and mushrooms), in the absence of any human or animal content (e.g., Koster, Crombez, Verschuere et al., 2004; Koster, Crombez et al., 2007; Öhman, Flykt et al., 2001; Vogt et al., 2008). A systematic examination of the IAPS (Lang et al., 1999, 2005), one of the most frequently utilised affective picture batteries, revealed that the depiction of humans is over-represented across high arousing positive and negative pictures relative to low arousing and neutral pictures, which predominately depict only inanimate objects or natural scenes and landscapes (Colden, Bruder, & Manstead, 2008). Living entities are likely to hold greater evolutionary significance compared to inanimate objects due to their ability to move. Demonstrating the importance of maintaining equal representation of animate stimuli across stimulus categories, a recent study found increases in skin conductance to be potentiated for negatively valenced pictures containing living elements (i.e., humans and animals) relative to negative pictures containing only inanimate objects (Tan, Li, Wang, & Yang, 2013). This finding highlights a potential confound in previous studies that have compared neutral and affectively valenced stimuli, such that variations in attentional orienting may reflect differences in the representation of

human versus inanimate objects, perhaps due to some automatic, empathy-driven process (Colden et al., 2008) or enhanced sensitivity to stimuli that have the propensity for movement, as opposed to specific differences in stimulus arousal or valence.

Previous studies examining the influence of stimulus valence and arousal on attention have typically relied on self-report ratings or existing IAPS normative data (Lang et al., 1999) when establishing affective stimulus categories. Self-report measures reflect only one aspect of the emotional response and are vulnerable to participant bias, social desirability, and individual differences in capacity for recognising momentary emotional states (i.e., alexithymia; Mauss & Robinson, 2009). Peripheral physiological responses have been shown to offer more direct indices of emotional reactivity that are less prone to these sources of bias (Bradley, Codispoti, Cuthbert et al., 2001; Lang et al., 1997; Mauss & Robinson, 2009; Sequeira, Hot, Silvert, & Delplanque, 2009). The current study therefore included physiological measures to validate the affective pictures, in addition to verbal ratings of valence and arousal.

Regarded as a precursory mechanism underlying the detection of stimuli within the environment (Öhman, 1979), the orienting response (OR) involves complex autonomic reactions, including increases in skin conductance and decelerated HR (Graham, 1979; Lynn, 1966; Maltzman & Boyd, 1984; Sokolov, 1963), which function to enhance awareness of a newly detected stimulus, thus facilitating attentional processing and the preparation of adaptive motor responses (Frith & Allen, 1983; Bradley, 2009; Rohrbaugh, 1984). Although earlier conceptualisations claim that the OR reflects the detection of novel stimuli occurring within the environment (Sokolov, 1963), later interpretations contest that the OR

cannot be explained by novelty alone and emphasise the importance of stimulus significance (Bernstein, 1979; Maltzman, 1979). Explaining the OR in terms of significance suggests that neurocognitive processes operate to evaluate whether or not a newly encountered stimulus is relevant to motivational needs (Bradley, 2009; Pendery & Maltzman, 1977). Not surprisingly then, physiological reactions indicative of the OR have been found to be potentiated following the presentation of affectively valenced stimuli, presumably reflecting the activation of motivational pathways in the brain (see Bradley, 2009 for a review).

Skin Conductance

Regarded as an important component of the OR, skin conductance responses (SCRs) are reflective of activity in the sympathetically innervated eccrine sweat glands, with heightened skin conductance associated with increased sweat secretion (Sequeira et al., 2009). Because eccrine sweat secretion is mediated by the sympathetic division of the autonomic nervous system, increased skin conductance serves as a physiological indicator of sympathetic arousal. Moreover, limbic and paralimbic brain regions that are involved in emotional processing, including the amygdala, hippocampus, basal ganglia and prefrontal cortex, have also been implicated in eccrine sweating (Critchley et al., 2000; Mangina & Beuzeron-Mangina, 1996; Zahn, Grafman, & Tranel, 1999), supporting the use of SCRs as an index of enhanced orienting toward affective stimuli.

Although the onset of novel stimuli typically elicits transient increases in skin conductance, irrespective of valence and arousal, the magnitude of the SCR has been found to be potentiated for affectively valenced material (Bradley, 2009). That is, phasic increases in skin conductance have been observed for both pleasant and unpleasant pictures relative to neutral pictures, revealing a curvilinear relationship

between verbal ratings of hedonic valence (pleasantness) and the magnitude of SCRs (Bradley, Codispoti, Cuthbert et al., 2001; Bradley, Miccoli, Escrig, & Lang, 2008; Winton, Putman, Krauss, 1984). Moreover, following repeated presentations, SCRs habituate faster for neutral pictures compared to positive and negative pictures (Bradley, Lang, & Cuthbert, 1993). Whereas stimulus novelty may adequately explain the occurrence of SCRs following exposure to seemingly innocuous material, motivational significance is regarded as playing a pivotal role in determining the magnitude SCRs for affectively valenced stimuli. Supporting this claim, the magnitude of SCRs observed during affective picture viewing has shown to share moderate to strong correlations with verbal ratings of stimulus arousal (Bradley, Codispoti, Cuthbert et al., 2001; Greenwald et al., 1989; Lang, Greenwald, Bradley, & Hamm, 1993).Within the context of motivational significance theory, SCRs are considered to reflect activation of the motivational systems (defensive or appetitive), with response magnitude corresponding to the degree of activation (Bradley, 2009; Bradley, Codispoti, Cuthbert et al., 2001; Lang et al., 1993).

Heart Rate

Transient reductions in HR have served as another favoured marker of the OR. While brief cardiac decelerations reflect that a stimulus has been detected or registered by the perceptual system, sustained deceleration is considered to indicate enhanced stimulus processing (Graham, 1979, 1992; Graham & Clifton, 1966; Kuniecki, Barry, & Kaiser, 2003; Lacey & Lacey, 1970). That is, the initial cardiac deceleration observed following stimulus onset may be sustained for several seconds before HR returns to baseline. This physiological phenomenon, referred to as fear bradycardia, is considered to reflect the initial reaction to a distant threat and has been consistently observed across numerous species, including *homo sapiens*

(Azevedo et al., 2005; Bethell, Holmes, MacLarnon, & Semple, 2016; Facchinetti, Imbiriba, Azevedo, Vargas, & Volchan, 2006). Current interpretations suggest that sustained cardiac deceleration is part of a defensive mechanism, promoting postural freezing when a threat is detected from a distance, thereby reducing the likelihood of detection from predators while facilitating greater sensory intake of the threatening stimulus (Arduino & Gould, 1984; Bradley, 2009; Eilam, 2005; Sagliano, Cappuccio, Trojano, & Conson, 2014). Supporting the assumption that decelerative cardiac responses are indicative of enhanced stimulus processing, studies have demonstrated enhanced cortical activity and better memory for affective pictures that prompt greater reductions in HR (Abercrombie, Chambers, Greischar, & Monticelli, 2008; Palomba, Angrilli, & Mini, 1997).

Lang et al. (1997) suggest that viewing aversive pictures (e.g., photographs of human mutilations) under laboratory conditions is analogous to perceiving a threat from a distance. Supporting this assumption, decelerated HR has been reliably observed in participants while viewing unpleasant, aversive pictures relative to pleasant and neutral stimuli (Abercrombie et al., 2008; Bradley, Codispoti, Cuthbert et al., 2001; Bradley et al., 2008; Greenwald et al., 1989; Moratti, Keil, & Stolarova, 2004; Palomba et al., 1997; Winton et al., 1984). Whereas Bradley, Codispoti, Cuthbert et al. (2001) observed initial cardiac deceleration following the onset of high arousing pleasant *and* unpleasant stimuli, pictures depicting human mutilations and attack scenes prompted more sustained deceleration relative to heterosexual erotica and other appetitive picture contents. In comparison to the unpleasant stimuli, the appetitive pictures were associated with a relative increase in HR following initial deceleration, consistent with a triphasic cardiac response (deceleration-acceleration-deceleration). Although these findings suggest that changes in HR are

augmented on the basis of valence, HR deceleration was also potentiated in response to high arousing, erotic pictures relative to less arousing pictures of families and nature, attesting to the role of stimulus arousal in determining cardiac reactivity (Bradley, Codispoti, Cuthbert et al., 2001). Indeed, some picture viewing studies have reported cardiac responses to vary as a function of stimulus arousal in addition to valence (Cuthbert, Bradley, & Lang, 1996; Lang et al., 1993), while others have reported comparable cardiac responses for pleasant and unpleasant visual stimuli that are matched on arousal (Codispoti, Surcinelli, & Baldaro, 2008; Sanchez-Navarro, Martinez-Selva, & Roman, 2005; Vrana, Spence, & Lang, 1988).

Although previous research has revealed physiological orienting that is augmented on the basis of both valence and arousal, the majority of picture rating studies have required participants to rate the pictures on these dimensions at the conclusion of each viewing trial, thereby increasing the task-relevance of the stimuli (e.g., Bradley, Codispoti, Cuthbert et al., 2001; Codispoti & De Cesarei, 2007; Greenwald, 1989; Lang et al., 1993; Winton et al., 1984). In the absence of any evolutionary or motivational significance, task-relevant stimuli are assumed to prompt orienting processes due simply to their relevance to current demands (Bradley, 2009). By combining the picture viewing and rating tasks, the physiological responses observed in previous picture viewing studies may partially reflect subjective appraisal processes, which are likely to vary as a function of both valence and arousal, rather than reflecting a pure measure of orienting.

Despite claims that rating instructions do not render specific stimuli as more or less relevant during picture viewing (Bradley, 2009), some studies have demonstrated that subjective appraisal processes are likely to vary as a function of both valence and arousal when participants are required to rate pictures according to

these dimensions (Purkis, Lipp, Edwards, & Barnes, 2009; Robinson, Storbeck, Meier, & Kirkeby, 2004). For example, Purkis et al. (2009) observed faster response latencies when participants rated low-arousing pleasant pictures in terms of valence and arousal compared to high-arousing pleasant pictures. Conversely, when participants rated unpleasant stimuli, faster ratings were given to high-arousing pictures compared to low-arousing pictures. These findings indicate that stimulus arousal has differential effects on evaluative processes for pleasant and unpleasant stimuli. A second difficulty emanating from combining picture viewing with a rating task comes from neuroimaging studies which have shown that heightened activation of limbic and paralimbic regions during passive viewing of aversive pictures is attenuated when participants are asked to rate the same pictures according to their subjective experiences (Hariri, Bookheimer, & Mazziotta, 2000; Hariri, Mattay, Tessitore, Fera, & Weinberger, 2003; Taylor, Phan, Decker, & Liberzon, 2003). Instead, viewing tasks that require explicit evaluations of affective content produce increased activation of the prefrontal cortex (Vuilleumier, 2005; Vuilleumier, Armony, & Dolan, 2004; Winston, O'Doherty, & Dolan, 2003). Considered together, it is likely that the physiological responses observed in previous picture viewing studies were influenced by evaluative processes involved in rating the stimuli, which have shown to vary between stimulus categories. This possibility brings into question whether physiological indices observed using a combined viewing-rating methodology are a valid reflection of ORs that correspond to heightened activation of limbic structures. To obtain a purer measure of the OR, picture viewing should occur in the absence of any instructions to rate the stimuli. Therefore, in addition to validating a novel set of affective stimuli, a secondary objective of Study 1 was to

determine whether physiological indices of the OR would be sensitive to stimulus valence and arousal during passive picture viewing.

In addition to combining viewing and ratings tasks into a single paradigm, few picture viewing studies have recorded and controlled for participants' subjective experiences of interest towards the pictures (e.g., Abercrombie et al., 2008; Bradley, Codispoti, Cuthbert et al., 2001; Bradley et al., 2008; Greenwald et al., 1989). Interest has been shown to share strong associations with verbal indices of valence and arousal, in addition to changes in skin conductance and HR (Cuthbert et al., 1996; Lang et al., 1993). In a study by Hamann, Ely, Grafton, and Kilts (1999), SCRs and cardiac deceleration for affectively pleasant and aversive pictures were comparable with responses elicited by unusual and interesting pictures that lacked emotional tone. Converging results from neuroimaging studies have demonstrated enhanced activation of the amygdala for interesting and ambiguous stimuli that were rated as neutral in valence and low in arousal (Hamann, Ely, Hoffman, & Kilts, 2002). By demonstrating that enhanced orienting can occur on the basis of interest and in the absence of affective content, these findings emphasise the need to control for interest before drawing conclusions about the influence of valence and arousal on physiological orienting.

Although some data support the motivational significance hypothesis of physiological orienting, firm conclusions cannot be drawn due to problems with the stimuli employed in previous studies. Moreover, no study has examined the effects of valence and arousal on the OR while controlling for interest using a passive viewing paradigm. To address the limitations of previous research, the present study employed well-established indices of the OR (SCR and HR) and a full factorial design in which the stimuli varied in valence (pleasant vs. unpleasant) and arousal

(high vs. low). Employing a novel set of motivationally significant pictures, the stimulus categories were chosen to reflect the natural-selective needs of humans. Unpleasant pictures depicted threats to physical wellbeing and included high (human mutilations; HAT) and low (interpersonal aggression; LAT) arousing content. Pleasant pictures contained appetitive content that was either high (heterosexual erotica; HAA) or low (infant nurturance; LAA) arousing. Potential confounds relating to stimulus content were controlled by ensuring that all pictures contained human elements, including the affectively neutral pictures, which depicted individuals engaged in mundane household activities. In order to elicit pure measures of physiological orienting, a passive viewing paradigm was employed. Verbal ratings of valence and arousal were obtained during a subsequent rating task, which was administered once all the pictures had been viewed. Ratings of interest were also recorded to determine whether associations between physiological ORs and verbal indices of motivational significance were over and above the effects of subjective interest.

Ratings of pleasure were expected to vary as a function of valence category, with higher ratings of pleasure hypothesised for pictures depicting heterosexual erotica and infant rearing compared to pictures of human mutilations and interpersonal aggression. In terms of arousal, pictures assigned to the high arousing stimulus categories (i.e., human mutilations and heterosexual erotica) were predicted to obtain higher arousal ratings compared to the low arousing stimulus categories (i.e., interpersonal aggression and infant rearing). If the OR is potentiated for motivationally significant stimuli, then physiological markers of enhanced orienting should be observed following high arousing stimuli despite the absence of instructions to rate the pictures. In accordance with the motivational model of

emotion (Bradley & Lang, 2007; Lang et al., 1997, 1998), SCRs and cardiac deceleration were hypothesised to be potentiated in response to the high arousing pictures, independent of valence, reflecting enhanced physiological orienting on the basis of motivational significance. Importantly, the subjective and physiological indices of arousal were expected to be comparable for the threatening and appetitive pictures after averaging over arousal category. In contrast, as predicted by the threat-superiority hypothesis (Öhman, Flykt et al., 2001; Öhman & Mineka, 2001), negatively valenced pictures reflecting threats to physical wellbeing (i.e., mutilated bodies and attack scenes) may hold special significance and prompt greater sensory intake relative to appetitive and neutral stimuli. A threat-superioirty bias would be reflected by an effect of stimulus valence, with more sustained cardiac deceleration and heightened SCRs observed in response to the negatively valenced pictures compared to the appetitive and neutral pictures.

Consistent with previous reports of positive correlations between ratings of stimulus arousal and the magnitude of SCRs (Bradley, Codispoti, Cuthbert et al., 2001; Greenwald et al., 1989; Lang et al., 1993), the same pattern of association was expected after controlling for ratings of interest in the present study. With respect to changes in HR, however, it was anticipated that the high arousing qualities of the heterosexual erotica used in the current study, and the relevance of these cues to our innate need to reproduce, would demand greater perceptual intake than has been previously observed for appetitive stimuli, particularly in studies that adopted heterogeneous stimulus categories (e.g., Greenwald et al., 1989; Lang et al., 1993). Specifically, after controlling for interest, it was predicted that changes in HR would be inversely associated with verbal indices of arousal, as opposed to valence,

corresponding to the degree to which the motivational pathways are activated by the pictures.

Method

Participants

A convenience sample of 43 participants, including 31 females (72.09%), was recruited from Bond University. The age of the participants ranged from 18 to 54 years (M = 25.79 years, SD = 9.78). All participants reported normal or corrected-to-normal vision and indicated that they found members of the opposite gender to be sexually appealing. Participants were recruited via distribution of an Explanatory Statement (Appendix A) and received course credit in return for their participation.

Materials

Picture stimuli. A novel stimulus set comprised of 90, 32-bit colour photographs (JPG format, 341 × 341 pixels) was developed for the current research. The set included five qualitatively distinct stimulus categories: low-arousing threat (LAT), high-arousing threat (HAT), low-arousing appetitive (LAA), high-arousing appetitive (HAA), and neutral. Five of the HAT pictures and two of the HAA pictures were sourced from the IAPS (Lang et al., 1999)[1]. All remaining pictures were acquired through internet picture searches and online image repositories. The HAT, LAT, HAA, and LAA categories were each comprised of 15 distinct pictures. To attenuate habituation to the affectively valenced stimuli, the neutral category included 30 pictures.

In addition to valence and arousal, the picture contents representing each category were selected to be symbolic of primary reinforcers relevant to the evolutionary needs of humans, including survival, procreation, and nurturance of

[1] IAPS identification numbers; HAT: 3000, 3010, 3053, 3060, 3069; HAA: 4672, 4693.

offspring. The LAT stimulus category was comprised of pictures reflecting human aggression and violence. Importantly, these pictures did not contain firearms, knives, or other contents that might be regarded as ontogenetic threats. The HAT pictures were selected to be both threatening and intensely arousing by depicting body envelope violations, including human blood injuries and mutilations. For the appetitive stimuli, the LAA category included pictures portraying infant rearing and nurturance of children. The HAA category was comprised of soft-core, heterosexual erotica. In sexually mature individuals, pictures depicting members of the opposite sex engaged in sexual activity are symbolic of reproductive opportunities and elicit a strong appetitive motivational state that is not prone to satiation (Bradley, Codispoti, Cuthbert et al., 2001). Finally, the stimulus set also included a neutral category of pictures that depicted people completing mundane household tasks (e.g., sweeping floors, polishing windows, hanging washing, etc.) In contrast to previous studies that have utilised pictures of inanimate objects or non-threatening plants (e.g., flowers and mushrooms), all of the neutral pictures contained human elements. Sample pictures from the five stimulus categories are shown in Figure 4.1.

Figure 4.1. Sample pictures from the low-arousing threatening, high-arousing threatening, neutral, low-arousing appetitive, and high-arousing appetitive stimulus categories.

The stimulus categories were matched on low-level, perceptual properties, including size, brightness and complexity. Using Adobe Photoshop C6 all pictures were digitally resized to 7.80 cm × 7.80 cm (subtending 7.4º × 7.4º). Averaged luminosity indices were obtained as a measure of brightness, with no significant differences observed across the stimulus categories, $F < 1$. To confirm that the stimulus categories were also matched on image complexity, a compression method was employed (cf. Buodo et al., 2002; Forsythe, Mulhern, & Sawey, 2008). This involved maximising the compression of each picture and using the resulting file size (bytes) as an index of complexity. Following compression, the preserved number of bytes did not vary significantly between the stimulus categories, $F < 1$.

Experimental hardware & software. The picture stimuli were displayed on a 19” IBM ThinkVision (C170) CRT monitor using SuperLab software (Version 4.0; Abboud, Schultz, & Zeitlin, 2008). The screen resolution was set to 1280 × 960 pixels, with a refresh rate of 85 Hz. Throughout the picture viewing task, skin

conductance, and HR were recorded continuously via a PowerLab Model 16/30 data acquisition system (ADInstruments, Sydney). A StimTracker Universal Event Marker Interface (Cedrus Corporation, San Pedro, CA) was used to mark the onset of each stimulus. All physiological data were recorded on a second Dell Precision T3600 computer running LabChart7 software.

Physiological measures. SCRs were recorded using a set of Ag/AgCl finger electrodes, filled with an isotonic electrolyte paste (TD-246 Electrode Paste; 0.5% saline), which were secured to the distal phalanges of the participants' index and ring fingers on the right palmer surface. Skin conductance was sampled at a rate of ~ 40 samples per second (40 Hz) and calibrated to a range of 40 µS. During data acquisition, the signals were filtered using a 1 Hz, second-order low-pass filter to minimise high frequency noise. A 0.05 Hz high-pass software filter was applied offline to remove the tonic component of the skin conductance signal and isolate the SCR.

To obtain a measure of the participants' HR, peripheral pulse signals were acquired using a piezoelectric pulse transducer attached to the distal phalange of the participants' left index finger. Pulse signals were amplified using an ADInstruments Bioamplifier and recorded at a rate of ~ 1000 samples per second (1000 Hz), with a range of 200-500 mV. Breathing artefacts were detected using an ADInstruments Model MLT1132 piezoelectric respiratory belt that was fastened around the participants' abdomen. To preserve the accuracy of the physiological measurements, trials coinciding with respiratory artefacts were removed.

Passive viewing task. Across 90 viewing trials, each picture was presented in the centre of the display monitor, against a grey background, for 6 s. To minimise anticipatory physiological responses, the inter-trial interval was randomised between

10 and 28 s. During this time, an empty screen was displayed, allowing the physiological indices to return to baseline. The viewing trials were divided into three blocks, with each block comprised of five pictures from the HAT, HAA, LAT, and LAA stimulus categories, in addition to 10 neutral pictures. Within each block, the presentation order followed a fixed, pseudorandomised sequence with no more than three consecutive presentations of pictures from the same stimulus category. The block sequence was counterbalanced across the sample and the presentation order reversed for every second participant.

Picture rating task. To obtain verbal indices of pleasure, arousal and interest for each picture, participants also completed a computer-administered picture rating task. Each trial commenced with a fixation cross (5 × 5 mm) for 1000 ms, followed by the presentation of a single picture, which remained onscreen for the remainder of the trial. After the picture had been displayed for 4 s, written instructions appearing at the top of the screen prompted participants to rate their subjective experiences of pleasure. A 9-point scale was presented beneath the picture, ranging from 1 (*extremely unpleasant*) to 9 (*extremely pleasurable*), with 5 corresponding to a neutral rating (*neither unpleasant nor pleasant*). Providing a graphical illustration of each point along the scale, a pictorial guide derived from the Self-Assessment-Manikin (SAM; Bradley & Lang, 1994; Lang, 1980) was also shown, ranging from a frowning, unhappy figure to a smiling, happy figure. Once a pleasure rating had been recorded, onscreen instructions directed participants to rate the picture on the basis of arousal. A 9-point arousal scale appeared concurrently beneath the picture, ranging from 1 = *extremely unaroused* to 9 = *extremely aroused*, and was accompanied by a SAM caricature that ranged from a relaxed, calm figure to an excited, wide-eyed figure (Bradley & Lang, 1994; Lang, 1980). After providing a

rating of arousal, onscreen text prompted participants to rate the picture according to interest, with the response scale ranging from 1 = *extremely uninteresting* to 9 = *extremely interesting*. The subsequent trial commenced immediately after a rating of interest was made. Participants recorded their ratings using a handheld numeric keypad and were advised that their responses were untimed. The rating task was comprised of three blocks of 30 trials each, with the pictures presented in the same sequence employed for the passive viewing task.

Procedure

Participants completed the experiment individually in a dimly lit, sound attenuated room and were monitored via a closed-circuit camera. Upon arrival to the laboratory, participants completed a consent form (Appendix B) advising about the graphic nature of some of the pictures and their right to withdraw from the study at any time, followed by a brief demographics questionnaire (Appendix C). Participants were subsequently seated in front of the display monitor at a distance of approximately 60 cm while the skin conductance electrodes, pulse transducer, and respiration belt were attached. The physiology sensors were attached approximately 5 minutes prior to the commencement of the passive viewing task, allowing absorption of the electrolyte paste and stabilisation of physiological signals. During this time, participants were provided with verbal instructions that emphasised the importance of attending to the pictures while minimising any physical movements. Participants were not advised of the subsequent rating task. The passive viewing task was initiated by the experimenter once the physiological traces were deemed to have stabilised and be free of artefacts. Participants were afforded a 2 minute break between trial blocks. Following completion of the third block of passive picture viewing, participants were familiarised with the ratings scales for the picture rating

task. Onscreen text reiterated the instructions prior to the commencement of the first picture rating trial. Once all the pictures had been rated, participants were debriefed and dismissed.

Results

Data Reduction

Viewing trials coinciding with movement and respiration artefacts were removed prior to statistical analysis of the electrodermal data (7.96% of trials). For the HR data, three participants were excluded from statistical analyses due to an inability to obtain a reliable pulse signal, and an additional seven cases were removed following the detection of artefacts on more than 25% of trials. Of the 33 cases that were retained, 13.10% of trials were discarded from the HR data due to artefacts.

SCRs were calculated by subtracting the average skin conductance level occurring 1 s before stimulus onset from the maximum increase in skin conductance amplitude occurring between 1 and 4 s post-stimulus onset, which is thought to reflect the window of initial orienting (Boucsein, 2012; Dawson, Schell, & Filion, 2007). Negative difference values were converted to zero before mean SCR magnitudes were calculated for the five stimulus categories (Boucsein, 2012; Dawson et al., 2007). To reduce positive skew and normalise the distributions, a logarithmic transformation [Ln(1 + SCR)] was applied to the SCRs prior to statistical analysis (Venables & Christie, 1980). Although statistical analyses were conducted using these transformed values, raw SCRs (μS) have been reported for descriptive statistics to preserve interpretability of the results.

For cardiac responses, pulse-to-pulse intervals were converted offline into HR in beats per minute (bpm). For each trial, bpm occurring 1 s prior to stimulus

onset were averaged, in addition to 12 discrete 500 ms windows during picture viewing, with each pulse-to-pulse interval weighted relative to the proportion of time occupied (Graham, 1980). Changes in HR were then calculated by subtracting the mean bpm occurring 1 s before stimulus onset from the average calculated for each 500 ms window during picture viewing (cf. Palomba et al., 1997). Negative difference values were reflective of HR deceleration.

Omnibus tests were considered significant at $p < .05$ and Bonferroni adjustment was applied to control for inflation of familywise error when following-up significant effects. In accordance with the conventions described by Cohen (1988), partial η^2 values of .01, .10 and .25 were used to define small, medium, and large effects, respectively. Although violations to sphericity were detected within the skin conductance and HR data, the pattern of results remained unchanged following a Greenhouse-Geisser correction and uncorrected degrees of freedom are reported here. The means and standard deviations for the verbal ratings and physiological indices are reported in Table 4.1 for each stimulus category.

Table 4.1

Means (Standard Deviations) of Verbal Ratings and Physiological Responses for Each Stimulus Type

	Threatening		Neutral	Appetitive	
Measurement	Low Arousing	High Arousing		Low Arousing	High Arousing
Pleasure rating	3.35 (0.96)	1.87 (0.80)	4.85 (0.84)	6.62 (0.98)	6.33 (1.11)
Arousal rating	5.30 (1.28)	6.07 (2.09)	3.66 (1.12)	5.33 (1.23)	6.41 (1.10)
Interest rating	5.63 (1.26)	6.21 (1.93)	2.80 (1.30)	5.44 (1.13)	6.16 (1.40)
SCR (μS)	0.12 (0.18)	0.21 (0.29)	0.09 (0.12)	0.09 (0.11)	0.27 (0.34)
HR change (bpm)*	-0.19 (2.06)	-0.89 (2.75)	0.04 (1.68)	-0.31 (2.39)	-1.63 (3.16)

Note. SCR = Skin conductance response; HR = Heart rate; bmp = beats per minute; *4-6 s post stimulus onset.

Verbal Ratings

To validate the stimulus categories in terms of valence and arousal, the verbal ratings were analysed first. Due to a computer recording error, verbal ratings for one participant were missing. Each rating type (pleasure, arousal, and interest) was subjected to a one-way, repeated-measures analysis of variance (ANOVA), with stimulus category serving as the within-subjects factor.

Hedonic valence. Analysis of the pleasure ratings demonstrated that the stimulus categories varied significantly in terms of hedonic valence, $F(4, 164) = 197.81$, $MSE = 0.86$, $p < .001$, $\eta_p^2 = .83$. Prior to following-up the effect of stimulus category, mean pleasure ratings obtained by the neutral pictures were subtracted from the mean ratings obtained by each of the other picture types. Values greater than zero were indicative of positive valence relative to neutral, whereas values less than zero reflected negative valence. To confirm that the stimulus categories reflected their intended valence, the differences values were analysed using a 2 × 2 repeated-measures ANOVA, with valence category (threatening vs. appetitive) and arousal (low vs. high) as factors. As depicted in Figure 4.2, an effect of valence category was observed, $F(1, 41) = 398.47$, $MSE = 1.57$, $p < .001$, $\eta_p^2 = .91$, with positive pleasure ratings obtained by the appetitive pictures ($M = 1.63$, $SE = 0.15$) and negative ratings obtained by the threatening pictures ($M = -2.24$, $SE = 0.15$). Pleasure ratings were also affected by whether the pictures were assigned to the low or high arousal categories, $F(1, 41) = 40.72$, $MSE = 0.80$, $p < .001$, $\eta_p^2 = .50$. Higher pleasure ratings were obtained by pictures assigned to the low arousing stimulus categories ($M = 0.14$, $SE = 0.11$) compared to pictures in the arousing categories ($M = -0.75$, $SE = 0.16$).

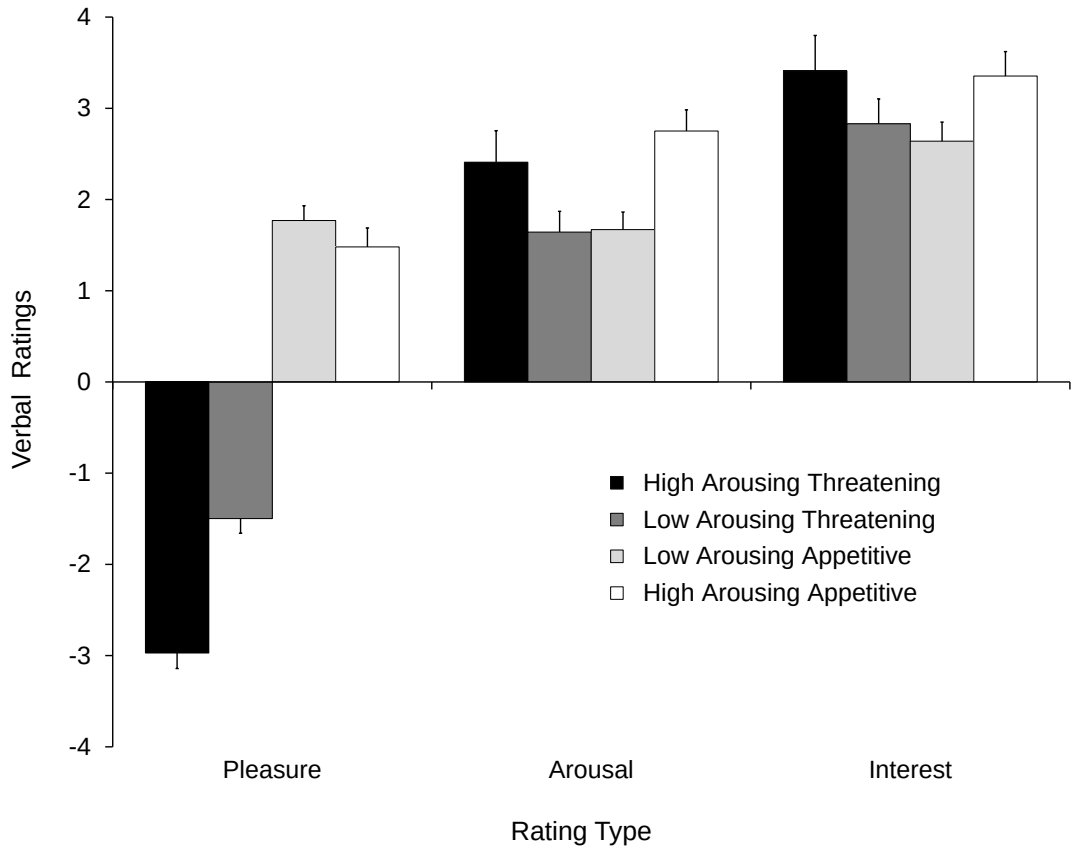

Figure 4.2. Verbal ratings of pleasure, arousal, and interest for the affective picture categories (N = 42). Zero = no difference from the neutral pictures. Error bars = standard errors.

Analysis of the pleasure ratings also revealed a Valence × Arousal interaction, $F(1, 41) = 24.63$, $MSE = 0.60$, $p < .001$, $\eta_p^2 = .38$. Significantly lower pleasure ratings were recorded for the HAT pictures (M = -2.97, SE = 0.17) compared to the LAT pictures (M = -1.50, SE = 0.16), $t(41) = 12.26$, $p < .001$, d = 1.89. Pleasure ratings for the HAA pictures (M = 1.48, SE = .21), however, did not varying significantly from ratings obtained for the LAA pictures (M = 1.77, SE = 0.16), $t(41) = 1.27$, $p = .213$, d = 0.20.

Arousal. Analysis of the arousal ratings also revealed an overall effect of stimulus type, $F(4, 164) = 33.77$, $MSE = 1.40$, $p < .001$, $\eta_p^2 = .45$. Difference values

were subsequently calculated by subtracting the mean arousal ratings obtained by the neutral pictures from those obtained by each of the other stimulus categories. The resulting indices reflected the degree of perceived arousal elicited by the pictures within that category relative to the neutral pictures. A 2 × 2 repeated-measures ANOVA revealed an effect of arousal category, $F(1, 41) = 38.37$, $MSE = 0.93$, $p < .001$, $\eta_p^2 = .48$. As can be seen in Figure 4.2, higher arousal ratings were obtained by pictures allocated to the high arousing picture categories ($M = 2.58$, $SE = 0.24$) compared to the low arousing picture categories ($M = 1.66$, $SE = 0.18$). The effect of valence and the Valence × Arousal interaction were nonsignificant, Fs ≤ 1.17.

Interest. Ratings of interest were also found to vary across the stimulus categories, $F(4, 164) = 45.69$, $MSE = 1.82$, $p < .001$, $\eta_p^2 = .53$. Consistent with the previous indices, the mean interest ratings obtained by the neutral pictures were subtracted from the mean interest ratings obtained by each of the other picture types. Higher difference values were indicative of greater interest relative to the neutral pictures. When the difference values for interest were analysed, a main effect of arousal category was found, $F(1, 41) = 11.75$, $MSE = 1.50$, $p = .001$, $\eta_p^2 = .22$. Pictures included in the high arousing stimulus categories ($M = 3.38$, $SE = 0.28$) were rated as more interesting compared to pictures in the low arousing categories ($M = 2.74$, $SE = 0.21$). The effect of valence category and the Valence × Arousal interaction were nonsignificant, Fs < 1.

Physiological Measures

Skin conductance. The mean amplitude of SCRs elicited by each stimulus category is depicted in Figure 4.3. To determine the effects of valence (threatening vs. appetitive) and arousal category (low vs. high), SCRs were subjected to a 2 × 2 repeated-measure ANOVA. When averaged over valence, SCRs were significantly

larger for the high arousing pictures (M = 0.24 µS, SE = 0.05) relative to the low arousing pictures (M = 0.11 µS, SE = 0.02), $F(1, 42) = 25.09$, $MSE = 0.02$, $p < .001$, $\eta_p^2 = .37$. Although the effect of valence was nonsignificant, $F < 1$, a significant Valence × Arousal interaction was observed, $F(1, 42) = 5.81$, $MSE = 0.01$, $p = .020$, $\eta_p^2 = .12$. The simple effect of arousal category was significant for the negatively valenced stimuli, with larger SCRs elicited by the HAT pictures relative to the LAT pictures, $t(42) = 3.31$, $p = .002$, $d = 0.50$. The effect of arousal category was even greater, however, for the appetitive pictures. Larger SCRs were prompted by the HAA pictures relative to the LAA pictures, $t(42) = 4.51$, $p < .001$, $d = 0.69$. As can be seen in Figure 4.3, the interaction reflected the large SCRs elicited by the heterosexual erotica relative to the pictures depicting infant rearing, which obtained SCRs responses that were comparable to the neutral pictures, $t(42) = 0.15$, $p = .885$, $d = 0.02$.

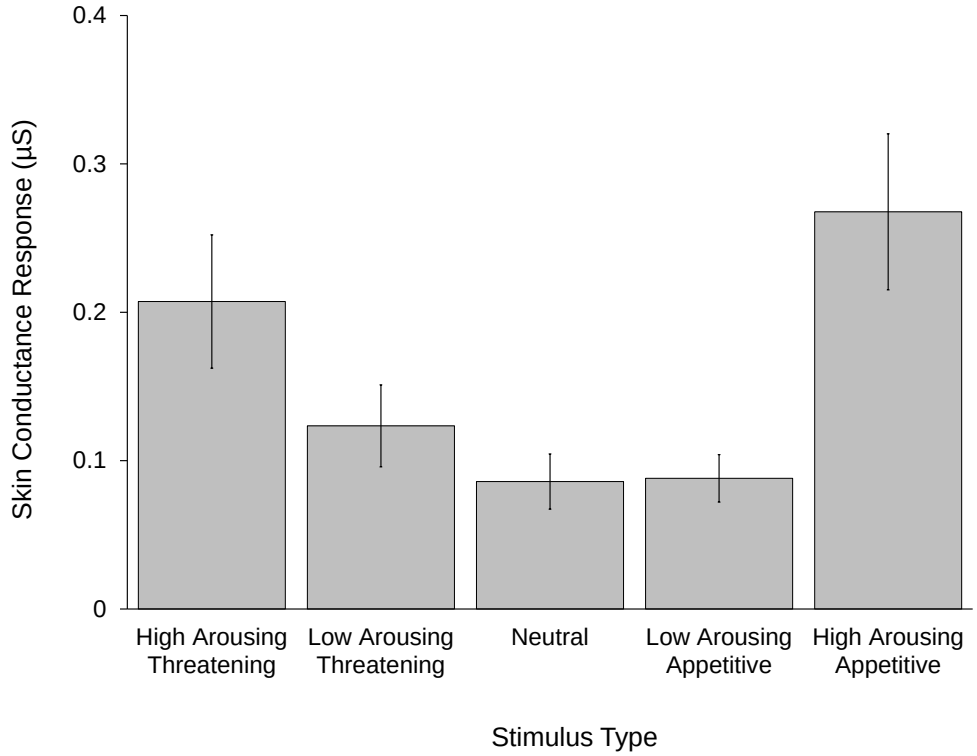

Figure 4.3. Untransformed skin conductance responses (µS) for the affective and neutral picture types (N = 43). Error bars = standard errors.

Cardiac responses. The mean changes in HR elicited by each stimulus type across the 6 s viewing period are plotted in Figure 4.4. To accurately depict the full HR waveform, the data were plotted in 500 ms bins post-stimulus onset. Prior to analysis, the 6 s viewing period was divided into three 2 s epochs (0-2 s, 2-4 s, and 4-6 s post-stimulus onset), consistent with the triphasic model of HR over time (Hodes, Cook, & Lang, 1985). The HR data were then analysed using a 5 × 3 repeated-measures ANOVA, with stimulus category and viewing epoch serving as within-subjects factors. Although the main effects of stimulus category and viewing epoch were nonsignificant, Fs ≤ 1.72, a significant interaction between these factors was observed, $F(8, 256) = 3.48$, $MSE = 1.43$, $p = .001$, $\eta_p^2 = .10$.

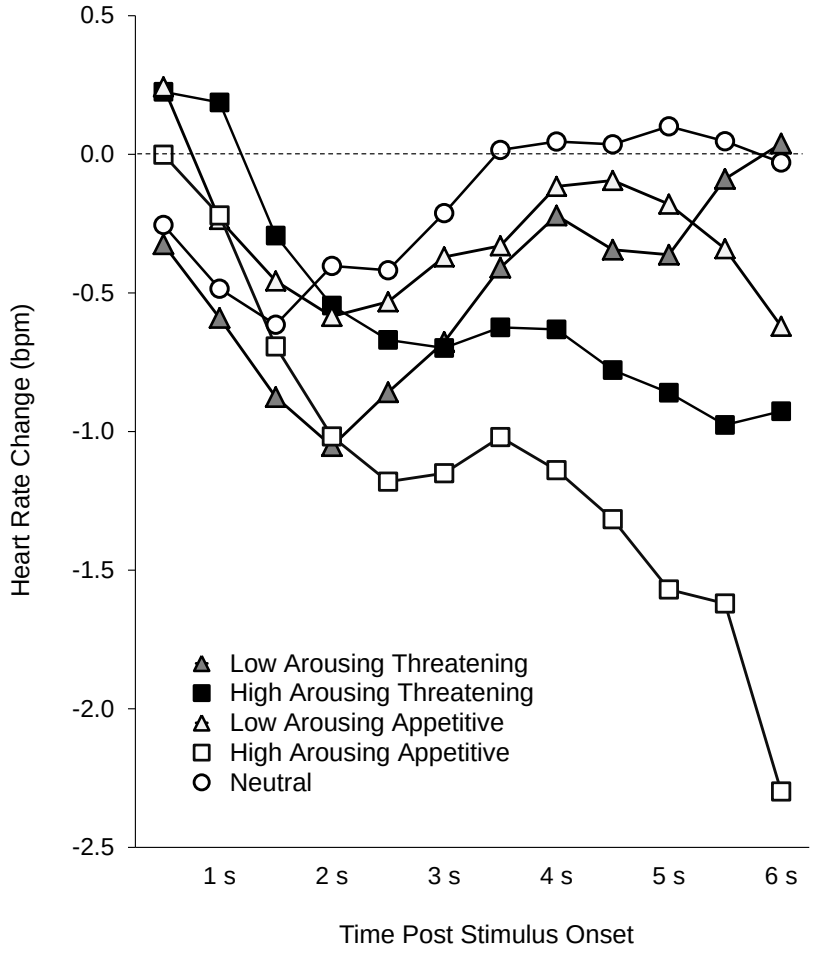

Figure 4.4. Mean changes in heart rate relative to pre-stimulus baseline elicited by each stimulus type across the 6 s viewing period (N = 33).

To follow-up the significant interaction, separate one-way ANOVAs were conducted to determine the effect of stimulus type within each viewing epoch. The effect of stimulus category was nonsignificant during the first (0-2 s) and second (2-4 s) viewing epochs, Fs ≤ 1.24. During the last viewing epoch (4-6 s), a significant effect of stimulus category was observed, $F(4, 128) = 3.36$, $MSE = 4.79$, $p = .012$, $\eta_p^2 = .10$. Changes in HR were found to vary as a function of arousal category, $F(1, 32) = 6.81$, $MSE = 5.28$, $p = .014$, $\eta_p^2 = .18$, with greater deceleration observed for the high arousing pictures (M = -1.29 bmp, SE = 0.43) relative to the low arousing pictures (M = -0.25 bpm, SE = 0.29). With respect to valence, HR deceleration did

not vary significantly between the threatening and appetitive pictures, $F < 1$. The interaction between valence and arousal was also nonsignificant, $F < 1$.

Picture Analysis

Before examining the association between the verbal ratings and physiological responses, the indices were averaged for each picture. Given that differences in cardiac responses between the stimulus categories were only observed during the last 2 s of picture viewing, the average change in HR occurring between 4 and 6 s post-stimulus onset was utilised to calculate the mean cardiac response for each stimulus.

As shown in Table 4.2, the mean verbal and physiological indices were subjected to preliminary correlation analyses. Bivariate scatterplots revealed a positive linear association between the average SCR and arousal rating obtained for each picture (Figure 4.5). In contrast, ratings of pleasure were found to share a quadratic relationship with SCRs (Figure 4.6). Indicative of a general valence effect, larger SCRs were observed for both pleasant and unpleasant pictures relative to the affectively neutral pictures. With respect to HR, sustained cardiac responses were found to share significant inverse associations with mean arousal and interest ratings. That is, greater reductions in HR were prompted by pictures rated as more arousing and interesting. Pleasure ratings were not significantly associated with cardiac responses.

Table 4.2

Bivariate Correlations between the Mean Verbal Ratings and Physiological Indices Obtained by the Pictures

Variable	1	2	3	4	5
1. Pleasantness Ratings	–				
2. Arousal Ratings	-.08	–			
3. Interest Ratings	-.13	.96**	–		
4. SCR (µS)	-.09	.59**	.51**	–	
5. HR change (bpm)	.01	-.41**	-.37**	-.36**	–

* $p < .01$. ** $p < .001$. *Note*. SCR = Skin conductance response; HR = Heart rate; bmp = beats per minute.

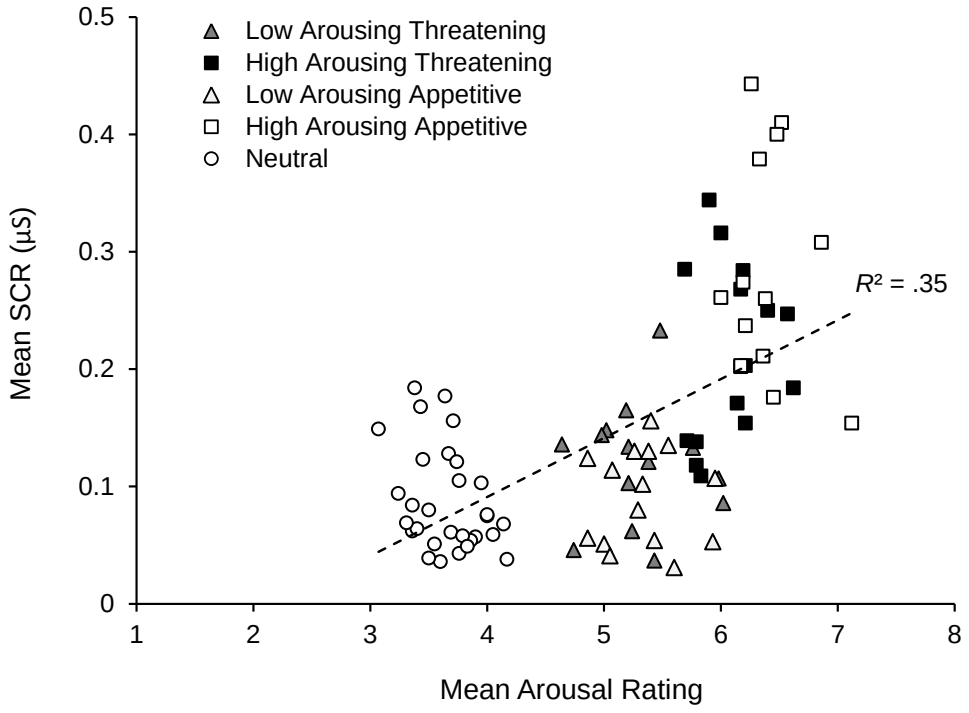

Figure 4.5. Bivariate scatterplot depicting the linear association between mean arousal ratings and skin conductance responses obtained by the pictures.

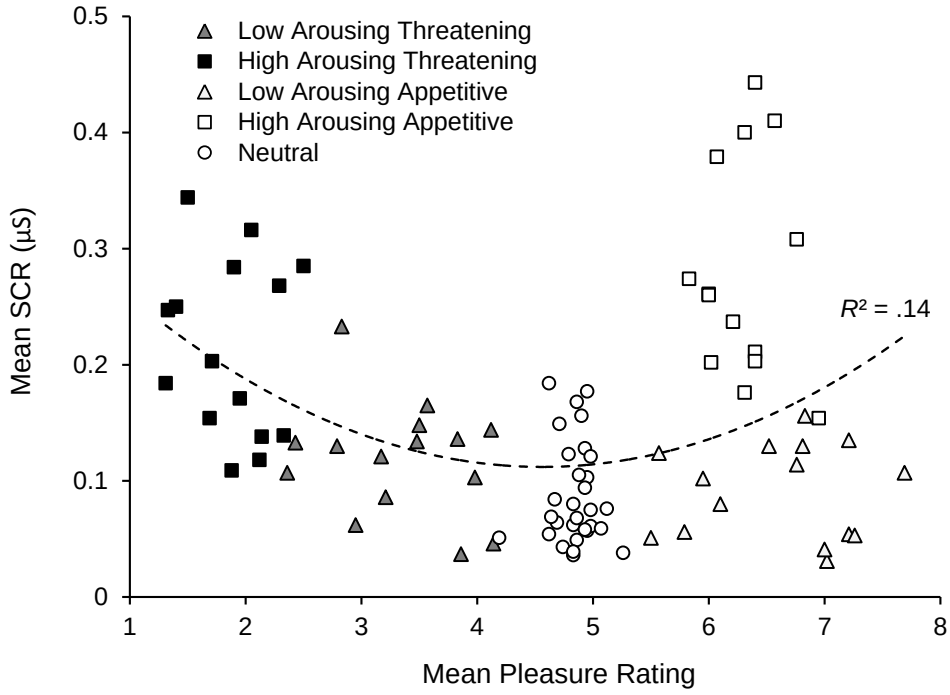

Figure 4.6. Bivariate scatterplot depicting the quadratic association between mean pleasure ratings and skin conductance responses obtained by the pictures.

To determine the degree of association between SCRs and participants' ratings of hedonic valence and arousal, after controlling for interest, a hierarchical polynomial regression was performed (Aiken & West, 1991). The average SCR obtained by each picture served as the criterion. Interest ratings were entered at Step 1 of the model, followed by arousal and pleasure ratings at Step 2. Due to the detection of multicollinearity, the linear predictors were mean centred prior to entry. The quadratic effect of valence was examined above the linear effects. Mean centered pleasure ratings were squared to calculate the quadratic term, which was entered at Step 3. The results of the hierarchical regression analysis are presented in Table 4.3.

Table 4.3

Hierarchical Multiple Regression Analysis Predicting Skin Conductance Responses from Interest, Arousal and Pleasure Ratings

Predictor	ΔR^2	β	*B*	*SE B*	95% CI for *B*
Step 1	.26**				
Constant			0.15	0.01	[0.13, 0.16]
Interest Ratings		.51**	0.03	0.01	[0.02, 0.04]
Step 2	.15**				
Constant			0.15	0.01	[0.12, 0.16]
Arousal Ratings		1.47**	0.12	0.03	[0.07, 0.18]
Pleasure Ratings		-.10	-0.01	0.01	[-0.02, 0.00]
Step 3	.01				
Constant			0.15	0.01	[0.13, 0.16]
Pleasure Ratings^2		-.18	-0.01	< 0.01	[-0.01, 0.00]
Total R^2 = .43**					

*p < .01. **p < .001. *Note*. N = 90; CI = confidence interval.

Once all predictor variables were entered into the model at Step 3, a significant proportion of variance in SCRs was accounted for, R^2 = .43, adjusted R^2 = .40, $F(4, 85) = 15.73$, $p < .001$. At the first step, interest ratings accounted for 26% of the variance in SCRs, $R^2_{change} = .26$, $F_{change}(1, 88) = 30.97$, $p < .001$. After controlling for interest, arousal and pleasure ratings accounted for an additional 15% of the

variance at Step 2, $R^2_{change} = .15$, $F_{change}(2, 86) = 11.17$, $p < .001$. Arousal was a significant predictor at Step 2, explaining 15% of unique variance in the magnitude of SCRs. Inclusion of the linear term for pleasure ratings did not significantly predict SCRs. At Step 3, the inclusion quadratic term for pleasure ratings did not result in a significant increase in explainable variance, $R^2_{change} = .01$, $F_{change}(1, 85) = 1.85$, $p = .178$. In the final model, only ratings of interest and arousal were significant predictors of SCRs, $\beta = -.90$, $p = .005$, and $\beta = 1.57$, $p < .001$, respectively. Interest ratings uniquely explained 6% of the variation in SCRs, whereas 16% unique variance was explained by the arousal ratings. The linear and quadratic terms for the pleasure ratings uniquely explained 1% each.

A second hierarchical regression analysis was performed, with mean changes in HR serving as the criterion. Interest ratings were entered at Step 1, followed by the arousal and pleasure ratings at Step 2. As reported in Table 4.4, the final model explained a significant amount of variability in sustained cardiac responses, $R^2 = .18$, adjusted $R^2 = .15$, $F(3, 86) = 6.33$, $p = .001$. Interest ratings explained 14% of the variance at Step 1, $R^2_{change} = .14$, $F_{change}(1, 88) = 14.21$, $p < .001$. At Step 2, after controlling for interest, the inclusion of arousal and pleasure ratings in the model did not significantly increase the explainable variance, $R^2_{change} = .04$, $F_{change}(2, 86) = 2.20$, $p = .117$. In the final model, arousal was the only significant predictor of sustained cardiac responses, $\beta = -.76$, $p = .043$. Arousal and interest uniquely explained 4% and 1% of the variance, respectively. Pleasure ratings did not uniquely explain any variance in sustained cardiac responses to the picture stimuli.

Table 4.4

Hierarchical Multiple Regression Analysis Predicting Sustained Changes in Heart Rate from Ratings of Interest, Arousal and Pleasure.

Predictor	ΔR^2	β	*B*	*SE B*	95% CI for *B*
Step 1	.14**				
Constant			-0.52	0.13	[-0.77, -0.27]
Interest Ratings		-.37***	-0.31	0.08	[-0.48, -0.15]
Step 2	.04				
Constant			-0.52	0.12	[-0.76, -0.27]
Arousal Ratings		-.76*	-0.86	0.42	[-1.68, -0.03]
Pleasure Ratings		< .01	0.00	0.08	[-0.15, 0.15]
Total R^2 = .18**					

*p < .01. **p < .001. *Note*. N = 90; CI = confidence interval.

Discussion

The current study was designed to validate a novel set of affective pictures using self-report ratings of valence and arousal, in addition to indices of physiological orienting. As shown in Figure 4.2, verbal ratings validated the categorisation of stimuli on the basis of hedonic valence and arousal. Pleasure ratings assigned to pictures of blood injuries (HAT) and interpersonal aggression (LAT) were lower than ratings given to the neutral pictures, indicative of negative valence. In contrast, pictures of infant rearing (LAA) and heterosexual erotica (HAA) were rated as more pleasurable than the neutral pictures, reflective of positive

valence. Combined, the threatening pictures received significantly lower pleasure ratings than the appetitive pictures, confirming that the stimuli reflected their intended valence categories. The significant Valence × Arousal interaction revealed that the HAT stimuli were rated as less pleasurable than then LAT pictures. This result was not surprising given that the HAT pictures were intended to depict intense threats to physical survival. In contrast, there was no difference in pleasure ratings between the low and high arousing appetitive pictures. As the sample was predominantly female, maternal drives may explain why the pictures of infant nurturance attracted comparable pleasure ratings relative to the erotic pictures. With respect to stimulus arousal, the high arousing pictures (HAT and HAA) were rated as more arousing than the low arousing pictures (LAT and LAA). Importantly, there was no difference in arousal ratings between the combined threatening and appetitive categories, indicating that the negative and positive pictures were matched on perceived arousal.

Regarding the physiological indices, all stimulus categories were found to prompt autonomic changes indicative of the OR, including increases in skin conductance and decelerated HR. This finding was not surprising given that each picture was presented only once during the passive viewing task, rendering all of the stimuli as "novel." If stimulus novelty alone determines the degree of orienting, however, as claimed by earlier conceptualisations of the OR (Sokolov, 1963), then changes in skin conductance and HR would have been comparable, irrespective of stimulus category. On the contrary, the data demonstrate significant variability in autonomic reactivity across the five categories of pictures.

In accordance with the motivational model of emotion (Bradley & Lang, 2007; Lang et al., 1997, 1998) and findings from previous research (Bradley,

Codispoti, Cuthbert et al., 2001), pictures in the high arousing stimulus categories were hypothesised to elicit heightened physiological responses indicative of the OR. Supporting these predictions, and consistent with the participants' subjective ratings of arousal, larger SCRs were observed for the HAT and HAA pictures compared to pictures in the low arousing stimulus categories. Overall, the pattern of skin conductance data is in agreement with earlier research (Bradley, Codispoti, Cuthbert et al., 2001; Greenwald et al., 1989; Lang et al., 1993), which found potentiated SCRs in response to pictures of mutilations and heterosexual erotica relative to less arousing picture contents. Replicating these earlier findings, the results revealed a strong, positive association between the verbal ratings of arousal and the magnitude of SCRs elicited by the stimuli. Pictures rated higher in arousal, however, were also rated as more interesting. Although previous studies have reported enhanced orienting for interesting and ambiguous pictures that lack affective valence (Hamann et al., 1999; Hamann et al., 2002), by statistically controlling for verbal interest ratings using hierarchical regression, the association between skin conductance and arousal ratings was found to be over and above the effects of interest. Although the amount of explainable variance in SCRs was enhanced when interest ratings were included in the regression model, interest explained 6% unique variance while arousal explained 16%. These findings demonstrate that variability in SCRs for the pictures is better attributed to differences in stimulus arousal than interest.

A U-shaped, quadratic association was observed between the magnitude of SCRs and ratings of pleasure, with increased SCRs for pictures rated as high *and* low in hedonic valence relative to the affectively neutral pictures. The quadratic term for the pleasure ratings, however, failed to explain a significant proportion of the variance in SCRs, once arousal and interest ratings had been statistically controlled.

In the context of motivational significance theory (Lang et al., 1997, 1998), results for the skin conductance data suggest that reactivity of the sympathetic nervous system in response to visual material corresponds to the motivational significance of the stimuli, as indexed by verbal ratings of stimulus arousal, independent of which motivational system is activated (defensive or appetitive).

Consistent with the skin conductance data, HR responses were also found to be augmented on the basis of stimulus arousal. As shown in Figure 4.4, pictures of heterosexual erotica and blood injuries prompted significantly greater cardiac deceleration relative to the other stimulus categories, as evidenced by sustained reductions in HR observed 4 to 6 s post-stimulus onset. Although decelerated HR in response to high arousing, unpleasant pictures is a relatively robust finding (e.g., Abercrombie et al., 2008; Azevedo et al., 2005; Bradley, Codispoti, Cuthbert et al., 2001; Bradley et al., 2008; Moratti et al., 2004; Palomba et al., 1997), comparable responses for high arousing, appetitive pictures have been less frequently observed, which has led some researchers to conclude that decelerative cardiac responses are determined on the basis of stimulus valence (Bradley, Codispoti, Cuthbert et al., 2001; Greenwald et al., 1989; Lang et al., 1993). In contrast, the threatening and appetitive pictures presented in the current study did not differ significantly in terms of HR deceleration. Moreover, regression analysis revealed that reductions in HR were better explained by verbal ratings of arousal, as opposed to pleasure, even after controlling for ratings of interest. Similarly, Sánchez-Navarro et al. (2005) found that changes in HR were associated with ratings of arousal, but did not correlate with ratings of valence. Collectively, these findings suggest that arousal plays a more pivotal role than valence in determining cardiac responses for visual stimuli. If it is accepted that decelerated HR in response to visual stimuli reflects enhanced

perceptual processing, the current findings suggest that reflexive orienting is biased toward high arousing stimuli, irrespective of whether they are perceived as threatening or appetitive.

The weaker cardiac responses reported for pleasant stimuli in previous studies may be an artefact of picture sampling, with appetitive stimuli frequently represented by heterogeneous sets of pictures that do not reflect natural-selective imperatives. In support of this explanation, Bradley, Codispoti, Cuthbert et al. (2001) observed greater cardiac deceleration for pictures depicting heterosexual erotica relative to other appetitive picture contents, including scenic landscapes, adventure sports, and appetising foods. Despite their appealing qualities, nature scenes and adventure sports are not representative of natural-selective needs, bringing into question their phylogenetic significance. In contrast, picture contents that are representative of primary reinforcers, such as heterosexual activity, are more likely to activate appetitive motivational pathways, as indexed by measures of arousal, while prompting prolonged orienting that is reflected by sustained reductions in HR. Additionally, while food reflects an opportunity for sustenance, the motivational significance of food-related cues is prone to satiation, which has been shown to strongly reduce cardiac reactivity (Buckhout & Grace, 1966; Drobes et al., 2001). In contrast, cues indicating the presence of a sexually receptive member of the opposite sex are less prone to satiation and are therefore likely to prompt more reliable physiological reactions.

The cardiac responses observed for the high arousing stimuli are consistent with the findings reported by Codispoti et al. (2008), Sánchez-Navarro et al. (2005), and Vrana et al. (1988), who also observed comparable decelerative responses for high arousing pleasant and unpleasant stimuli. Similar to the methodology adopted

here, in these studies physiological measures were recorded during passive viewing and in the absence of a combined rating task. In studies that have required participants to rate the stimuli at the conclusion of each viewing trial (e.g., Bradley, Codispoti, Cuthbert et al., 2001; Codispoti & De Cesarei, 2007; Greenwald, 1989; Lang et al., 1993; Winton et al., 1984), cardiac responses are likely to be strongly influenced by anticipation of prompts to rate the stimuli. Considering that subjective appraisal processes vary as a function of both arousal and valence, as demonstrated by Purkis et al. (2009), it is possible that a combined rating task may differentially attenuate cardiac deceleration for high arousing appetitive stimuli, perhaps by inducing a potentiated acceleratory response that is absent during passive viewing.

Assuming that the OR is a precursor to enhanced stimulus processing, the current findings converge with results from numerous cognitive paradigms that have demonstrated attentional biases for motivationally significant stimuli (see Yiend, 2010 for a review). The data are also consistent with neuroimaging studies which have found heightened activation of limbic structures and the visual cortex in response to both high arousing appetitive and threatening visual stimuli (Bradley et al., 2003; Garavan et al., 2001). Through connections with the hypothalamus, brainstem, and other brain regions, the amygdala is thought to regulate autonomic arousal in response to emotionally arousing stimuli, including changes in HR and skin conductance (LeDoux, 2000; Davis & Whalen, 2001), consistent with the pattern of physiological responses observed in the present study. These findings, however, have been shown to vary as function of task instructions, with heightened activation of limbic and paralimbic brain regions observed under conditions of passive viewing, but attenuated when viewing is combined with a subjective rating task (Hariri et al., 2000; Hariri et al., 2003; Taylor et al., 2003). In contrast to

previous picture viewing studies (e.g., Bradley, Codispoti, Cuthbert et al., 2001; Codispoti & De Cesarei, 2007; Greenwald et al., 1989; Lang et al., 1993; Winton et al., 1984), by separating the viewing and rating tasks, the current procedure ensured that all stimuli were equivalent in terms of their task-relevance and avoided a potential confound associated with differential higher-order appraisal processes. Therefore, in addition to demonstrating that motivationally significant cues can prompt potentiated physiological orienting in the absence of a combined rating task, the current data are likely to reflect automatic, amygdala-driven processes involved in emotional processing, as opposed to higher-order, conscious processes that underlie subjective appraisal.

The data yielded from Study 1 support the assumption that stimuli which are relevant to our natural-selective needs, including both threatening and appetitive pictures, can prompt physiological orienting that is mediated on the basis of stimulus arousal. Within the context of the motivational model of emotion (Bradley & Lang, 2007; Lang et al., 1998), the physiological responses that were observed can be explained on the basis of motivational significance, as indexed by the degree of subjective arousal evoked by the stimuli. The current findings therefore demonstrate that the extent to which the defensive or appetitive motivational systems are activated determines the magnitude of the OR, as opposed to which motivational system is engaged. This interpretation challenges theories that adopt the notion of a threat-superiority bias (Öhman, Flykt et al., 2001; Öhman, Lundqvist et al., 2001; Pratto & John, 1991) by suggesting that the degree of motivational significance underlies physiological orienting toward stimuli occurring within the visual field, as opposed to the degree of negative valence or the presence of threatening features.

Chapter Summary

Study 1 validated a novel set of biologically-relevant pictures that varied in both valence and arousal. As predicted, participants assigned lower pleasure ratings to pictures of blood injuries (HAT) and human aggression (LAT) than heterosexual erotica (HAA) and pictures depicting child rearing (LAA). In terms of arousal, pictures of human aggression and child rearing were rated as less arousing than pictures of blood injuries and erotica. The findings from Study 1 also affirm that reactivity of the autonomic nervous system to motivationally significant pictures is determined on the basis of stimulus arousal. Irrespective of valence, SCRs and cardiac deceleration were more pronounced for high arousing pictures (blood injuries and erotica) than low arousing pictures (human aggression and child rearing). Autonomic reactivity was found to share a strong association with verbal ratings of arousal, even after controlling for subjective interest. Arguing against a threat-superiority bias, physiological responses did not vary as a function of hedonic valence. Rather, the data indicated that the magnitude of the OR was determined on the basis of motivational significance, as indexed by arousal.

CHAPTER V

STUDY 2

Assuming that the OR facilitates attentional processing, the findings from Study 1 converge with results from previous studies that have demonstrated attentional biases for high arousing stimuli (Buodo et al., 2002; Schimmack, 2005; Vogt et al., 2008). The specific components of spatial attention that are affected by stimulus arousal and the time-course of such biases, however, remain unclear. The SCT provides a method for disentangling the components of attention (i.e., engagement, disengagement and IoR) and examining the extent to which they are affected by affective stimuli. Surprisingly few studies employing this task, however, have investigated the independent effects of stimulus valence and arousal on attentional orienting.

Vogt et al. (2008) administered the SCT to a nonselect sample and found that high arousing pictures prompted slower responses relative to low arousing pictures, independent of valence. This result was only observed on the invalid trials, in which the probes and cues appeared in opposite peripheries. Given that participants needed to shift their attention away from the cued location before responding to the probe, this finding suggests that the high arousing stimuli were associated with delayed attentional disengagement. On valid trials, during which the probes appeared in the same location as the cues, no differences in RTs were observed, indicating that attentional engagement was not facilitated on the basis of valence or arousal. Although Vogt et al. (2008) concluded that attentional biases are best explained in terms of delayed disengagement from high arousing stimuli, the exposure duration of the cues was not varied, with all pictures presented for 150 ms. Consequently, it is not possible to rule out that attention was affected by specific picture types at earlier

or later stages of processing. That is, because only a single exposure condition was employed, Vogt et al. (2008) cannot attest to the time-course of biased attentional processing toward the affectively valenced pictures.

Highlighting the importance of cue duration in determining which attentional processes are observed using SCT, the typical finding of faster RTs on valid trials compared to invalid trials has been shown to reverse following longer cue presentations (Posner & Cohen, 1984). For example, in a study by Waters et al. (2007), participants responded faster on invalid trials compared to valid trials when cues were exposed for 500 ms, irrespective of whether the cues were negatively or positively valenced. The reverse cue validity effect suggests a general avoidance of the cues during later stages of information processing and is consistent with IoR. In the low anxious participants, the reverse cue validity effect was enhanced for aversive pictures compared to pleasant and neutral pictures, indicating that attention shifted away from the aversive stimuli more readily than the other cue types. As suggested by the authors, in non-anxious individuals attentional avoidance may function to regulate mood by restricting processing of aversive stimuli. Because Waters et al. (2007) did not include briefer exposure conditions, however, it is unknown whether avoidance of the threatening pictures was preceded by biased attentional engagement or delayed disengagement.

By including brief exposure conditions, Koster, Crombez et al. (2007) were able to confirm the presence of attentional bias towards threatening pictures in non-anxious participants. Following 100 ms of cue exposure, highly threatening pictures facilitated responses on valid trials, and delayed responses on invalid trials, thus demonstrating both facilitated engagement and delayed disengagement during early stages of information processing. Consistent with Waters et al. (2007), at longer cue

exposure durations of 200 ms and 500 ms, responses for validly cued probes were significantly faster when preceded by neutral relative to threatening pictures. This finding suggests that during later stages of information processing, attention to threat can be inhibited, perhaps as a means of regulating mood by limiting the processing of aversive stimuli (Ellenbogen & Schwartzman, 2009; Ellenbogen, Schwartzman, Stewart, & Walker, 2002; Ellenbogen, Schwartzman, Stewart, & Walker, 2006). With respect to appetitive stimuli, a meta-analysis by Pool et al. (2016) demonstrated that attentional biases for positively valenced cues are more reliably observed under brief cue-probe delays, indicating that enhanced attention for appetitive stimuli occurs rapidly and affects initial shifting of attention to a cued location.

In addition to the duration of cue exposure, the detection of attentional biases is also strongly influenced by the ratio of valid to invalid trials. When a high proportion of the trials are valid (e.g., 75%), task performance is benefited by attending to the cued location, since this is where the probe will appear on the majority of trials. Under these conditions, the cues are rendered task-relevant and attract top-down, endogenous processes, including voluntary allocation of attention to the cued location (Jonides, 1981; Posner, Snyder, & Davidson, 1980; Ruz & Castillo, 2002). In contrast, when the ratio of valid to invalid trials is equal (i.e., 50:50), the probe is no more likely to appear in the cued location compared to the noncued location. Given that the cues do not predict where the probe will appear above chance, there is no incentive to voluntarily attend to them. By rendering the cues irrelevant to the task, shifts of attention are less likely to be endogenously motivated and more likely to reflect bottom-up, exogenous processes (Lupiáñez et al., 2004). Consequently, the attentional processes being examined are likely to varying according to the ratio of valid to invalid trials employed.

Previous studies that have failed to observe facilitated attentional engagement using the spatial cueing paradigm have typically employed a higher proportion of valid relative to invalid trials (e.g., Fox et al., 2001; Sagliano, Trojano et al., 2014; Vogt et al., 2008). It has been argued, however, that the task-relevance of attending to the cues is likely to mask faster RTs for valid trials using affectively valenced stimuli when compared with valid neutral trials (Koster, Crombez et al., 2007; Mogg & Bradley, 1998). Considering that responses are generally faster for valid trials, and that the effect of cue validity is potentiated when the cues accurately indicate the location of the probe on the majority of trials, further speeding of responses following motivationally significant or threat-related cues is perhaps unlikely (Fox et al., 2001). Moreover, given that facilitated attentional engagement of affective stimuli is assumed to occur exogenously, it is not surprising that studies reporting evidence of this effect have adopted an equal ratio of valid to invalid trials (e.g., Koster, Crombez et al., 2007; Van Damme et al., 2004). Conversely, evidence of delayed disengagement is more reliably observed under conditions that promote endogenous processes, such as when cues are rendered task-relevant due to a proportionately higher number of valid trials (e.g., Fox et al., 2001; Fox et al., 2002; Vogt et al., 2008).

Employing a stimulus set that varied in both valence and arousal, Study 2 aimed to determine whether the allocation of spatial attention to affective stimuli is facilitated on the basis of threat or arousal, after controlling for individual differences in state and trait anxiety. To investigate the individual and combined effects of valence and arousal on the distinct components of attention, the SCT was administered to samples of nonselect participants, using the pictures validated in Study 1. Extending on the findings reported by Vogt et al. (2008), systematic

variations in task parameters, including the exposure duration of the cues and the ratio of valid to invalid trials, were manipulated across the experiments reported in the present chapter. To maintain methodological consistency with previous spatial cueing studies that have reported evidence of biased attention (Fox et al., 2001; Koster, Crombez et al., 2004; Koster, Crombez et al., 2006; Koster, Crombez et al., 2007; Massar et al., 2011; Vogt et al., 2008), a probe localisation task was adopted, whereby participants indicated the location of the probes. The use a of probe localisation task was further justified by Salemink, van den Hout, and Kindt (2007), who demonstrated that attentional biases are more reliably observed when participants are required to simply detect the probes as opposed to discriminating between two visually distinct probes.

Assuming that the length of cue exposure corresponds to the stage of attentional processing that is probed, multiple exposure durations were included to provide information on the time-course of attentional processing. Exogenous, bottom-up processes are assumed to operate exclusively following very brief exposure to the cues (≤ 100 ms), whereas relatively longer exposure durations (> 100 ms) allow for endogenous, top-down processes to occur (Bar-Haim et al., 2007; Cisler & Koster, 2010). Accordingly, restricted exposure conditions (≤ 100 ms) were intended to capture attentional engagement effects, while longer exposure conditions were included to examine delayed disengagement (400 ms) and avoidance (1000 ms).

In addition to investigating the effect of exposure duration, the influence of top-down endogenous processes was manipulated between experiments by varying the ratio of valid to invalid trials. When the proportion of valid and invalid trials was equal (50:50), the cues were assumed to attract stimulus-driven, exogenous

processing. In contrast, when the predictive value of the cues was enhanced by increasing proportion of valid relative to invalid trials (75:25), a combination of exogenous and endogenous processes were assumed to operate. The task parameters that were varied across experiments are detailed in Table 5.1.

Table 5.1

Variations in Parameters for the Spatial Cueing Task Administered in Study 2

Experiment	Cue Validity	Exposure Conditions
Experiment 2.1	50:50	100 ms*, 400 ms, 1000 ms
Experiment 2.2	75:25	100 ms*, 400 ms, 1000 ms
Experiment 2.3	50:50	24 ms, 59 ms, 100 ms*

Note. *Due to the refresh rate of the monitor (85 Hz), the exact duration of stimulus exposure for the 100 ms exposure condition was 106 ms.

General Methodology

Participants

Samples recruited for the subsequent studies were comprised of undergraduate students from Bond University, who received course credit in exchange for their participation. Convenience sampling was facilitated via distribution of an Explanatory Statement (Appendix A) and an online participant recruitment system (SONA).

Responses on a demographics questionnaire (Appendix C) revealed that all participants had normal or corrected-to-normal vision. Due to the heterosexual nature of the high arousing appetitive stimuli, the demographics questionnaire also asked participants to indicate whether or not they considered members of the opposite gender to be sexually appealing. Only participants who reported a heterosexual orientation were included in the final samples. Written informed consent was obtained from all participants prior to the commencement of experimental procedures (Appendix B).

The combined sample (N = 137) included 108 females (78.83%). The age of the participants ranged from 18 to 63 years (M = 23.94, SD = 8.36). Two participants (1.46%) reported a homosexual orientation. Data obtained from these participants was removed prior to statistical analysis. Participant details for the individual samples are reported in the Method section of each experiment.

Materials

State-Trait Anxiety Inventory. Given the robust findings of attentional biases to threat in anxious individuals (Bar-Haim et al., 2007), the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg & Jacobs, 1983; Appendix D) was administered to provide an index of the participants' experiences

of transient (state) and dispositional (trait) anxiety. Comprised of 40 items, the STAI includes two distinct scales. The state anxiety scale (STAI-S) consists of 20 statements reflecting one's current affective state, including transitory feelings of nervousness, discomfort and physiological arousal. For example, one item read "I am presently worried over possible misfortunes." Using a 4-point Likert scale, participants were required to rate their current experiences, with responses ranging from 1 (*not at all*) to 4 (*very much so*). The remaining 20 items comprised the trait anxiety scale (STAI-T), which asked about the participants' general experiences of anxiety, including enduring dispositions of stress, propensity for worrying, and vulnerability to experiencing anxious discomfort. For example, one item read "I lack self-confidence." Participants were required to rate each item on a 4-point Likert scale ranging from 1 (*not at all*) to 4 (*almost always*), according to how they generally feel. To reduce acquiescence bias and haphazard responding, 10 items on the STAI-S and nine items on the STAI-T were reverse worded. Reponses to these items were reverse scored prior to calculating the totals for each scale. Total scores could range from 20 to 80, with higher scores reflecting elevated experiences of state and trait anxiety, respectively.

The STAI-S and STAI-T demonstrate strong internal consistency, with Cronbach's alpha coefficients ranging between .86 and .95 (Speilberger et al., 1983). The STAI-T also exhibits strong temporal reliability, with test-retest coefficients ranging between .73 and .86 following 30- and 60-day intervals. Given the transitory nature of state anxiety, scores on the STAI-S tend to have lower temporal stability, ranging from .36 for females and .51 for males (Speilberger et al., 1983). Demonstrating strong concurrent validity, scores obtained on the STAI-T have been shown to correlate with other measures of anxiety, including the Taylor Manifest

Anxiety Scale (Taylor, 1953) and the Anxiety Scale Questionnaire (Cattell & Sheier, 1963), with correlation coefficients ranging from .73 to .85 (Spielberger & Reheiser, 2004). Elevated scores on STAI-S have been obtained from respondents undergoing stressful situations, including school exams and military training programs, compared to scores following relaxation procedures, thereby indicating that the scale has good construct validity (Speilberger et al., 1983).

Picture stimuli. From the set of 90 pictures employed in Study 1, 72 pictures were selected to serve as cues for test trials on the SCT. The final set included 12 pictures from the LAT, LAA, HAT, and HAA stimulus categories, in addition to 24 neutral pictures. As with Study 1, each picture was digitised to a size of 7.80 cm × 7.80 cm (subtending 7.4º × 7.4º) and presented in 24-bit colour.

The final exemplars for each stimulus category were informed on the basis of mean ratings of pleasure and arousal obtained for each picture in Study 1. As depicted in Figure 5.1, pictures included in the threatening stimulus categories were selected to have lower ratings of pleasure relative to the neutral pictures, reflecting negative valence. In contrast, pictures for the appetitive stimulus categories were selected to have higher ratings of pleasure relative to the neutral stimuli, reflecting positive valence. Selection criteria also ensured that the threatening and appetitive pictures were matched on ratings of arousal, while maximising the divergence between the low and high arousing stimulus categories. Neutral stimuli were selected to have lower ratings of arousal compared to the other stimulus categories. To maximise homogeneity within the stimulus categories, the mean ratings of pleasantness and arousal of each picture needed to approximate the mean of its category. Box-and-whiskers plots generated for each stimulus category revealed an absence of outliers with respect to the mean ratings of pleasure, arousal and interest

obtained by each of the pictures. Mean pleasure and arousal indices obtained by the stimulus categories are reported in Table 5.2. The complete stimulus set can be viewed in Appendix E.

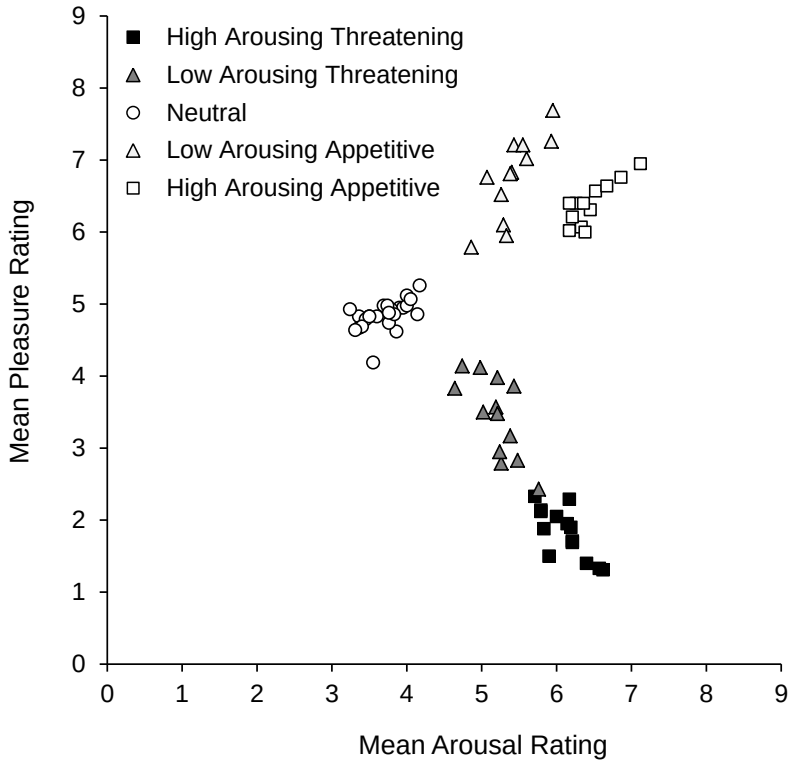

Figure 5.1. Scatter plot of the mean pleasure and arousal ratings obtained by each picture used for test trials on the spatial cueing task.

Table 5.2

Means and Standard Deviations for Affective Characteristics and Low-Level Perpetual Features of the Different Stimulus Categories

	Threatening				Appetitive					
	Low Arousing		High Arousing		Low Arousing		High Arousing		Neutral	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Pleasure Rating	3.33	0.62	1.83	0.41	6.64	0.67	6.33	0.29	4.85	0.21
Arousal Rating	5.29	0.44	6.15	0.30	5.36	0.35	6.31	0.18	3.70	0.27
Interest Rating	5.57	0.37	6.25	0.24	5.48	0.47	6.08	0.17	2.82	0.35
SCR (μS)	0.11	0.03	0.24	0.07	0.10	0.04	0.26	0.10	0.07	0.02
Heart Rate Δ	-0.18	1.18	-0.79	0.62	-0.48	1.37	-1.44	1.01	0.04	1.15
Luminance (Mean)	122.96	15.52	118.74	18.52	120.90	22.41	122.22	19.00	127.92	15.65
Luminance (*SD*)	66.07	9.16	60.22	13.65	57.51	9.94	56.26	9.83	55.32	9.67
Colour saturation	120.50	16.43	117.08	19.29	119.16	21.33	119.70	17.97	126.09	16.69
Complexity (Bytes)	1899.83	82.61	1984.58	202.33	1874.17	167.91	1829.50	108.81	1874.13	150.72

Affective dimensions. To confirm that the motivationally significant pictures selected for the test trials varied as intended in terms of valence and arousal, item-level analyses were performed using the mean verbal and physiological indices calculated for each picture in Study 1. The mean pleasure ratings were subjected to 2 × 2 ANOVA, with valence (threatening vs. appetitive) and arousal (low vs. high) serving as between-subjects factors. As intended, average pleasure ratings obtained by the appetitive pictures (M = 6.49, SE = 0.11) were significantly higher compared to ratings obtained by the threatening pictures (M = 2.58, SE = 0.11), $F(1, 44)$ = 678.62, MSE = 0.27, $p < .001$, $\eta_p^2 = .94$. Pleasure ratings were also found to vary as a function of arousal category, with lower pleasure ratings obtained by the high arousing pictures (M = 4.08, SE = 0.11) compared to the low arousing pictures (M = 4.99, SE = 0.11), $F(1, 44) = 36.46$, MSE = 0.27, $p < .001$, $\eta_p^2 = .45$. This effect, however, was subsumed by a Valence × Arousal interaction, $F(1, 44) = 15.72$, MSE = 0.27, $p < .001$, $\eta_p^2 = .26$. Pleasure ratings assigned to the HAT pictures (M = 1. 83, SE = 0.15) were significantly lower compared to ratings for LAT pictures (M = 3.33, SE = 0.15), $t(22) = 7.00$, $p < .001$, d = 2.92, whereas ratings were comparable for the low (M = 6.64, SE = 0.15) and high arousing (M = 6.33, SE = 0.15) appetitive pictures, $t(22) = 1.48$, $p = .150$, d = 0.65. Given the graphic nature of the HAT pictures, which were intended to reflect intense threats to physical wellbeing, these stimuli were predicted to be characterised by extremely low pleasure ratings.

A second two-way ANOVA was performed on the mean arousal ratings calculated for each picture. This analysis confirmed that pictures allocated to the high arousing stimulus category obtained significantly higher arousal ratings (M = 6.27, SE = 0.07) compared to pictures in the low arousing stimulus category (M = 5.32, SE = 0.15), $F(1, 44) = 88.16$, MSE = 0.12, $p < .001$, $\eta_p^2 = .67$. Importantly, the

effect of valence category was nonsignificant, $F(1, 44) = 2.34$, $MSE = 0.12$, $p = .133$, $\eta_p^2 = .05$, indicating that subjective arousal was comparable between the threatening and appetitive pictures. The Valence × Arousal interaction was also nonsignificant, $F < 1$. The pattern of results obtained for the verbal indices of arousal was replicated using the mean SCRs elicited by the pictures. An effect of arousal category demonstrated larger SCRs for the high arousing pictures ($M = 0.25$ µS, $SE = 0.01$) relative to the low arousing pictures ($M = 0.11$ µS, $SE = 0.01$), $F(1, 44) = 56.09$, $MSE = 0.23$, $p < .001$, $\eta_p^2 = .56$. The effect of valence category and the Valence × Arousal interaction were nonsignificant, Fs < 1, indicating that the appetitive and threatening pictures did not vary in terms of physiological arousal. These data confirm that pictures allocated to the high arousing stimulus categories elicited greater physiological and subjective arousal compared to pictures in the low arousing stimulus categories. Importantly, the data also demonstrate that the threatening and appetitive pictures were matched on arousal.

To further validate the stimulus categories, participants recruited for each of the subsequent studies in the current thesis were also asked to rate the pictures in terms of pleasure and arousal. For each experiment, participant-level analyses were performed on the rating data and yielded a consistent pattern of results. For the sake of brevity, the results reported here pertain to the combined sample ($N = 240$)[2]. If participants completed more than one experiment, only their original rating data were analysed.

A within-subjects ANOVA confirmed that pleasure ratings varied significantly as a function of picture type, $F(4, 956) = 816.65$, $MSE = 1.20$, $p < .001$,

[2] Analyses were repeated with experiment included as a factor to determine whether verbal ratings for the pictures varied across studies. The effect of experiment and its interaction with picture type were nonsignificant, confirming that the ratings were consistent across experiments.

η_p^2 = .77. For each participant, mean pleasure ratings obtained by the neutral pictures were subtracted from the mean ratings obtained by each of the other cue types. The resulting difference values were than analysed using a 2 × 2 ANOVA to determine the effects of valence and arousal category. Consistent with the results of the item-level analysis, pleasure ratings were significantly higher for the appetitive pictures (*M* = 2.25, *SE* = 0.10) compared to the threatening pictures (*M* = -1.73, *SE* = 0.09), *F*(1, 239) = 2012.69, *MSE* = 1.88, *p* < .001, η_p^2 = .89. Pleasure ratings were also found to vary according to arousal category, *F*(1, 239) = 118.43, *MSE* = 0.82, η_p^2 = .33, with lower pleasure ratings obtained by the high arousing pictures (*M* = -0.06, *SE* = 0.10) relative to the low arousing pictures (*M* = 0.58, *SE* = 0.07). The effect of arousal was subsumed by a significant Valence × Arousal interaction, *F*(1, 239) = 34.98, *MSE* = 0.83, *p* < .001, η_p^2 = .13. As can be seen in Figure 5.2, there was a strong effect of arousal category on pleasure ratings for the threatening pictures, *t*(240) = 19.29, *p* < .001, *d* = 1.31, with lower ratings of pleasure assigned to the HAT pictures (*M* = -2.22, *SE* = 0.10) compared to the LAT pictures (*M* = -1.23, *SE* = 0.08). Arousal category had a similar, albeit smaller, effect on pleasure ratings for the appetitive pictures, *t*(240) = 2.72, *p* = .007, *d* = 0.19, with lower ratings obtained by the HAA pictures (*M* = 2.10, *SE* = 0.13) compared to the LAA pictures (*M* = 2.39, *SE* = 0.09).

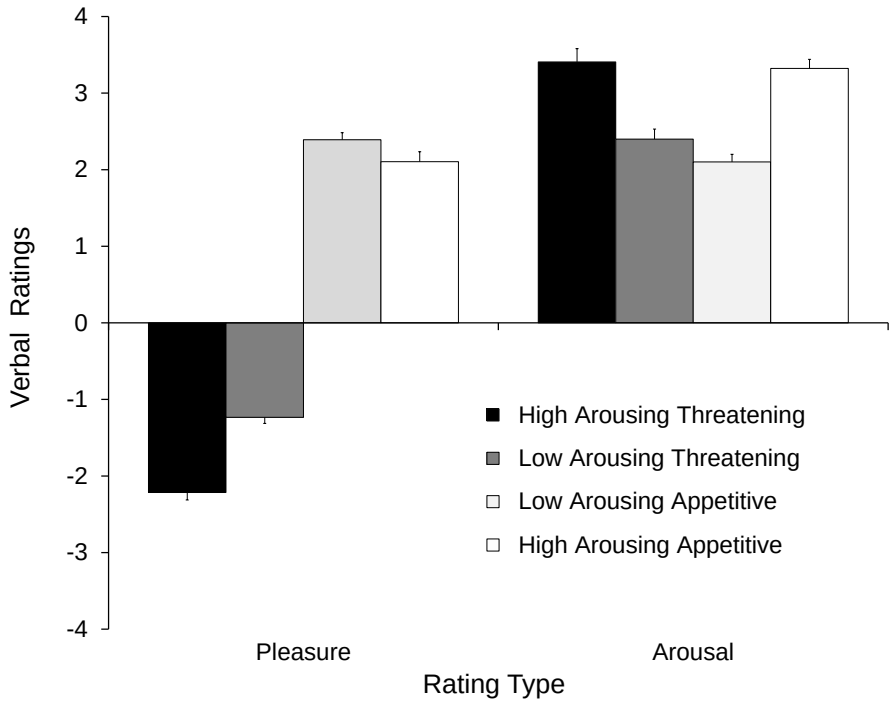

Figure 5.2. Verbal ratings of pleasure and arousal for affective pictures (*N* = 240). Zero = no difference from the neutral pictures. Error bars = standard errors.

Arousal ratings also varied according to stimulus type, $F(4, 956) = 234.03$, $MSE = 1.95$, $p < .001$, $\eta_p^2 = .50$. After subtracting the mean arousal ratings provided for the neutral pictures from the arousal ratings obtained for the other picture types, arousal ratings were subjected to a two-way ANOVA. In agreement with results from the item-level analyses, an effect of arousal category was observed when the ratings were averaged over picture valence, $F(1, 239) = 270.63$, $MSE = 1.10$, $p < .001$, $\eta_p^2 = .53$. Participants gave higher arousal ratings to pictures allocated to the high arousing picture categories ($M = 3.37$, $SE = 0.13$) compared to pictures in the low arousing categories ($M = 2.25$, $SE = 0.10$). The effect of valence category was nonsignificant, $F(1, 239) = 2.57$, $MSE = 3.41$, $p = .110$, $\eta_p^2 = .01$, as was the Valence × Arousal interaction, $F(1, 239) = 2.85$, $MSE = 0.96$, $p = .092$, $\eta_p^2 = .01$. These data confirm that the high arousing pictures were indeed perceived as more arousing

compared to the low arousing pictures, while the threatening and appetitive pictures were regarded as equivalently arousing.

The pattern of results reported for the combined data set was replicated when the picture ratings obtained in each experiment were analysed separately. The consistency of the picture rating data indicates that the selected pictures reliably represented their overarching categories in terms of valence and arousal.

Low-level perceptual features. Physical properties, such as picture brightness, contrast, colour saturation, and complexity, have been shown to increase the salience of stimuli and enhance bottom-up processing (Bradley, Hamby, Löw, & Lang, 2007; Parkhurst & Niebur, 2005). To ensure the pictures utilised for the experimental trials were matched on these properties, mean luminance and colour saturation values were computed for each picture using Adobe Photoshop CS6 software (cf. Calvo & Lang, 2005; Ochsner, 2000). Additionally, the standard deviation of luminance for each picture was also recorded as an index of image contrast. An objective measure of picture complexity was obtained by digitally compressing each picture (JPEG format) and recording the resulting file size in bytes (cf. Buodo et al., 2002), with larger file sizes reflecting greater picture complexity. Descriptive statistics for the low-level, perceptual features of each stimulus category are reported in Table 5.2. One-way ANOVAs revealed no significant differences in luminance and colour saturation between the stimulus categories, Fs < 1. The file size of the pictures following digital compression did not vary significantly between categories, $F(4, 67) = 1.82$, $MSE = 22009.73$, $p = .136$, $\eta_p^2 = .10$, indicating that picture complexity was also consistent across categories.

Spatial cueing task. Across the remaining studies, participants completed a computer-administered SCT, designed to measure the distinct components of

attentional bias toward the motivationally significant pictures. As illustrated in Figure 5.3, each trial commenced with the presentation of three equally sized, white placeholder boxes (8.00 cm × 8.00 cm, subtending 7.6º × 7.6º), which were presented against a grey background. One placeholder box was positioned in the centre of the screen and was flanked by the two remaining boxes on the left and right. The centre of each peripheral box was 8.70 cm (8.3º) from a fixation cross (5 mm × 5 mm) positioned in the centre of the middle box. The three placeholder boxes and central fixation cross remained onscreen for the entire duration of each trial. Presenting the fixation cross continuously throughout each trial was intended to discourage overt eye movements (cf. Petrova, Wentura, & Bermeitinger, 2013). After the placeholder boxes and fixation cross had been exposed for 500 ms, a single picture was presented within either the left or right box. The picture filled the entirety of the placeholder box in which it appeared. To examine the time-course of biased attentional processing, the exposure duration of the cues was manipulated. As specified in Table 5.1, three exposure conditions were incorporated into each experiment. A small black diamond (6 mm × 6 mm, subtending 0.6º × 0.6º) served as the probe stimulus, which appeared 12 ms (1 refresh rate) following the offset of the cue. The probe stimulus appeared in either the same location as the preceding cue (valid trials) or the contralateral location (invalid trials). The participants' task was to respond as quickly as possible to the probe by indicating its location, left or right. Manual responses were made by pressing one of two buttons, corresponding to left or right, on a Cedrus response box (RB-530). After a response was registered, there was an intertrial interval of 1000 ms before the next trial was initiated.

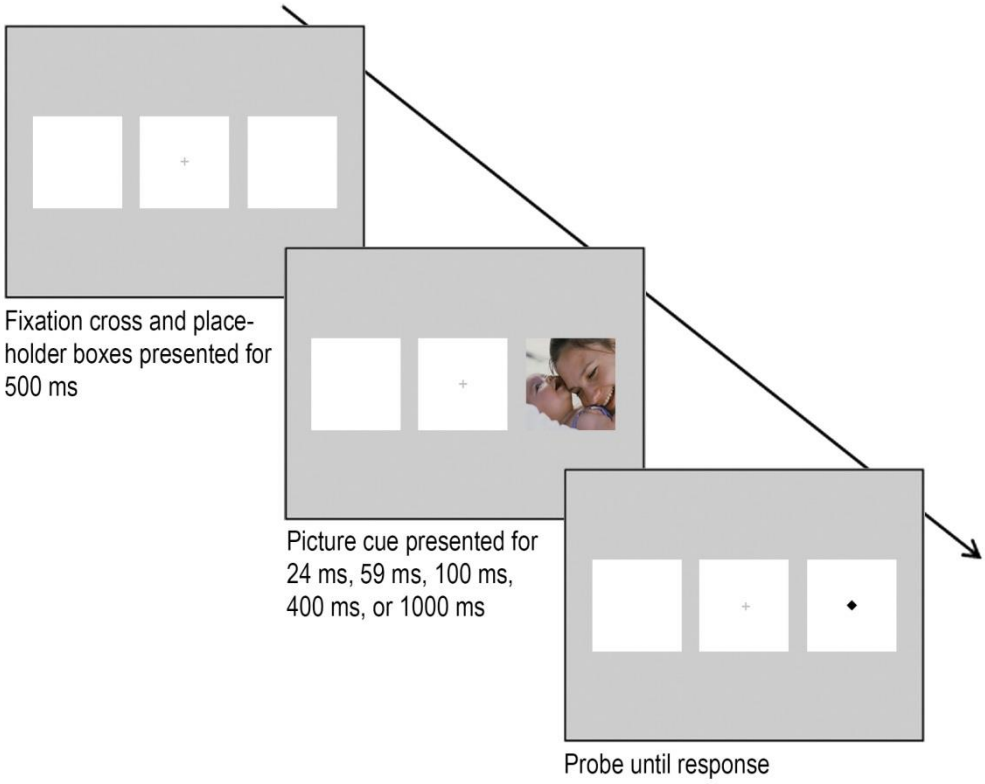

Figure 5.3. An example of a valid trial on the spatial cueing task in Study 2. During invalid trials, the picture cue and the probe appeared in opposite spatial locations.

The SCT included a total of 288 test trials, which were divided equally into four blocks. Each block included an equal number of LAT, LAA, HAT, and HAA cues, with 12 unique pictures representing each cue type. To minimise habituation toward the motivationally significant pictures, there were twice as many neutral cues relative to the other cue types. Rather than doubling the frequency of exposure to each neutral item, the number of unique pictures that comprised the neutral stimulus category was twice that of the other cue types. Each block utilised the same set of stimuli as cues, with no stimulus repetitions occurring within the blocks. Thus, during a single administration of the task, each picture served as a cue on four occasions, once per block. The exposure duration of the cues and the frequency of left and right presentations were also equated within each block. For each

experiment, the picture stimuli were counterbalanced across exposure conditions and presentation location (left or right). That is, across participants, all stimuli were presented to the left and right periphery with equal frequency at each exposure duration. Depending on the ratio of valid to invalid trials, pictures served as valid cues on either 50% (Experiments 2.1 & 2.3) or 75% (Experiment 2.2) of trials in which they were used. In each administration of the task, valid and invalid cues were presented equally often to the left and right peripheries. Trial sequences were pseudo-randomised such that no more than two presentations of any one stimulus type occurred successively and there were no more than three consecutive presentations to the same location or for the same exposure duration. Due to variations in the ratio of valid to invalid trials, further details regarding the counterbalancing are provided in the Method sections of each experiment.

To ensure participants were responding to the location of the probe and not the cues, an additional 24 catch trials were randomly dispersed across the blocks. On these trials, the probe was not presented following the offset of the cue, requiring participants to withhold a response and await the next trial. If participants did not respond to the cue, the trial timed-out after 4000 ms and the next trial was initiated. Assuming that participants completed the task by responding to the location of the probes and not the cues, as was intended, the frequency of catch trial responses was expected to be low. In contrast, a high proportion of catch trial responses would indicate that the participant responded to the location of the cues, as opposed to the probes. Pictures used for the catch trials included four of the remaining neutral pictures from Study 1, and two pictures from the LAT, LAA, HAT, and HAA categories that had not been selected for the test trials.

To familiarise participants with the SCT, 24 practice trials were administered prior to the commencement of the first block of test trials. The practice trials utilised an additional six, neutrally valenced pictures that were not used for the test or catch trials.

Picture rating task. Adopting the same rating task administered during Study 1, participants were asked to provide verbal ratings of pleasure, arousal and interest for each picture that served as a cue during the SCT test trials. Each picture was preceded by a fixation cross for 1000 ms and remained onscreen until the participant had made all three ratings. Manual responses were made using a handheld numeric keypad. For the pleasure and arousal ratings, a visual analogue scale adopted from the Self-Assessment-Manikin (SAM; Bradley & Lang, 1994; Lang, 1980) was presented below the picture to help guide the participants' responses. Pictures were presented and rated in the same order in which they appeared during the SCT. There were four blocks of picture rating trials, with 18 pictures presented within each block.

Experimental hardware & software. A Dell Precision T3600 computer with an Intel Xeon 3.00Ghz processor was used to administer the experimental tasks on a 19" IBM ThinkVision (C170) CRT monitor, displaying a refresh rate of 85 Hz. Stimuli were presented at a resolution of 800 × 600 pixels in 32-bit colour. The spatial cueing and picture ratings tasks were developed and administered using Inquisit Lab 4 software package (De Clercq, Crombez, Roeyers, & Buysse, 2003). Synchronising with the vertical retrace interval of the monitor, Inquisit facilitates tachistoscopic presentation of visual stimuli with millisecond precision. For the SCT, participants' responses were made using a Cedrus RB-530 response pad, which offers built-in RT measurement with 1 millisecond resolution. A Targus handheld

numeric keypad was used during the picture rating task to facilitate the participants' ratings of the picture stimuli.

Procedure

All participants were tested individually in a dimly lit, sound attenuated laboratory. The experimenter was located in an adjacent room during completion of the experimental tasks and monitored participants via a closed-circuit video camera. Upon arrival at the laboratory, participants provided informed consent, after which the demographics questionnaire and STAI (Speilberger et al., 1983) were administered. Following completion of the pencil-and-paper measures, participants were seated approximately 60 cm from the display monitor, and provided with verbalised instructions for completing the SCT. Participants were instructed to respond to the probes as quickly as possible, while preserving accuracy, by pressing the button on the response box that corresponded to its location (left or right). The experimenter emphasised that the participant should only respond to the location of the probe, and not the cues. To minimise voluntary eye movements, participants were instructed to fixate their eyes on the central fixation cross at all times throughout the task. These instructions were reiterated prior to the commencement of each block via onscreen text. After receiving the task instructions, participants completed 24 practice trials followed by 312 experimental trials (288 test trials + 24 catch trials) divided into four blocks of 78 trials each. Participants were afforded a 2 minute break between blocks. Following completion of the SCT, the rating task was administered. Participants were provided with standardised instructions regarding the three rating scales (pleasure, arousal and interest), emphasising the anchors of each scale. Participants were advised that their responses on the rating task would not be

timed. Once ratings had been provided for all of the pictures, participants were debriefed and dismissed.

Design

Each experiment in Study 2 adopted a 2 × 2 × 2 × 3 repeated-measures design. The independent factors were cue valence (threatening vs. appetitive), arousal (low vs. high), validity (valid vs. invalid), and exposure duration (100 ms[3] vs. 400 ms vs. 1000 ms [Experiments 2.1 & 2.2], and 24 ms vs. 59 ms vs. 100 ms[3] [Experiment 2.3]), all of which were varied within-subjects. The primary dependent variable was RT, defined as the latency between the onset of the probe and the participant's manual response on correct trials. To control for individual differences in trait anxiety, participants' scores on the state and trait subscales of the STAI (Speilberger et al., 1983) were entered as covariates. In separate analyses, the proportion of correct responses was also analysed to exclude the possibility of a speed-accuracy trade-off. Typically, however, the number of errors made on the SCT is low (Koster et al., 2004; Koster, Crombez, Verschuere, & De Houwer, 2006; Vogt et al., 2008; Waters et al., 2007).

Data Preparation & Analysis

Data reduction. For test trials on the SCT, the RT data were reduced using the same procedures adopted by previous spatial cueing studies (e.g., Koster, Crombez, Van Damme et al., 2004; Koster, Crombez et al., 2007; Vogt et al., 2008; Waters et al., 2011). For each participant, RTs for incorrect responses were discarded. Correct responses that occurred faster than 150 ms and slower than 750 ms were also removed, as these data were considered to be reflective of anticipatory and overly delayed responding, respectively. Of the remaining data, outlying

[3] Due to the refresh rate of the monitor (85 Hz), the exact duration of stimulus exposure for the 100 ms exposure condition was 106 ms.

responses were eliminated on a case-by-case basis, defined as RTs falling beyond ± 2 *SD*s from the participant's mean for each experimental condition.

Planned analyses. To determine the individual and combined effects of stimulus valence and arousal on the allocation of attention to motivationally significant stimuli, RT data were analysed using a 2 × 2 × 2 × 3 repeated-measures analysis of covariance (ANCOVA), with valence (threatening vs. appetitive), arousal (low vs. high), validity (valid vs. invalid), and exposure duration (100 ms vs. 400 ms vs. 1000 ms [Experiments 2.1 & 2.2] and 24 ms vs. 59 ms vs. 100 ms [Experiment 2.3]) as within-subjects factors. To control for individual differences in state and trait anxiety, STAI-S and STAI-T scores were included as covariates. STAI scores were mean centered prior to analysis, thereby ensuring accurate estimates of within-subjects effects and avoiding inflation of Type II error rates (Delaney & Maxwell, 1981; Schneider, Avivi-Reich, & Mozuraitis, 2015).

In the event that interactions involving valence, arousal, and validity were significant, cue validity indices (CVIs) were calculated to provide a general measure of attention for the motivationally significant pictures. CVIs were determined by subtracting RTs for valid trials from RTs for invalid trials, separately for each cue type:

$$CVI = RT_{\text{Invalid Cue}} - RT_{\text{Valid Cue}}$$

If the cues attracted and maintained attention, it was reasoned that faster responses would be observed for probes appearing in the same spatial location (valid trials) relative to probes appearing in the opposite periphery (invalid trials), resulting in a positive CVI. Conversely, if attention shifted away from the cues and was inhibited from returning to the cued location, responses would be slower on valid

trials compared to invalid trials, resulting in a negative CVI. To determine the relative effects of valence and arousal, CVIs for the neutral cues were subtracted from the CVIs calculated for each of the other cue types. Positive values therefore indicated that attention oriented more readily toward that particular cue type relative to the neutral cues. Negative values, on the other hand, indicated weaker attentional orienting compared to the neutral cues. Provided that the omnibus analyses yielded higher-order interactions between the affective qualities of the cues and validity, follow-up tests were performed using CVIs to determine how attention was generally affected by the motivationally significant pictures.

To test hypotheses regarding the distinct components of spatial attention, indices of attentional engagement and disengagement were calculated for each cue type. RTs for probes that were validly cued by motivationally significant pictures were subtracted from RTs for probes validly cued by neutral pictures, providing a measure of attentional engagement:

$$\text{Engagement Index} = RT_{\text{Valid/Neutral Cue}} - RT_{\text{Valid/Motivationally Significant Cue}}$$

If attentional engagement was enhanced by a particular cue type, the cues should have facilitated faster responding to probes appearing in the same location (valid trials) compared to the neutral cues. Engagement indices greater than zero therefore reflected facilitated engagement of the cues, whereas values less than zero indicated attentional avoidance. To yield an index of attentional disengagement, RTs for probes that were invalidly cued by neutral pictures were subtracted from RTs for probes invalidly cued by motivationally significant pictures:

$$\text{Disengagement Index} = RT_{\text{Invalid/Motivationally Significant Cue}} - RT_{\text{Invalid/Neutral Cue}}$$

If attentional disengagement was delayed for a particular cue type, the cues should have slowed responses to probes appearing in the opposite periphery (invalid trials) relative to the neutral cues. A positive disengagement index therefore reflected that disengagement from the cues was delayed, whereas a negative value indicated speeded disengagement. For both indices, a value of zero reflected no difference from the neutral stimuli and therefore an absence of attentional bias. To determine whether the components of spatial attention were affected by the motivationally significant cues, engagement and disengagement indices were compared against zero using single sample *t*-tests.

An alpha level of $p < .05$ was employed to determine the statistical significance of the analyses. Bonferroni corrected *p* values were calculated for *a priori* and post-hoc follow-up tests to control for inflation of familywise error. Adopting Cohen's (1988) conventions, η_p^2 values of .01, .10 and .25 were considered to reflect small, moderate and large effects, respectively. All analyses were performed using SPSS (version 22).

Experiment 2.1

Experiment 2.1 was designed to determine whether the allocation of attention to motivationally significant stimuli is determined by valence, arousal, or their interaction. Extending on the findings reported by Vogt et al. (2008), the SCT administered during Experiment 2.1 was optimised to examine multiple components of spatial attention, including engagement, disengagement, and avoidance, by employing three exposure durations: 100 ms, 400 ms, and 1000 ms. On the basis of previous research, facilitated engagement of the motivationally significant pictures

was anticipated to occur in the brief exposure condition (i.e., 100 ms), whereas delayed disengagement and attentional avoidance were anticipated to occur under intermediate (i.e., 400 ms) and extended (i.e., 1000 ms) exposure conditions that provided greater opportunity for strategic processes to operate (Cisler & Koster, 2010; Koster, Crombez, Verschuere, Van Damme et al., 2006; Koster, Crombez et al., 2007; Mogg et al., 2004).

In the spatial cueing study by Vogt et al. (2008), high arousing cues slowed responses on invalid trials, consistent with delayed disengagement. On valid trials, however, there was no difference in RTs following the presentation of the different cue types, suggesting that attentional engagement was unaffected by valence and arousal. The absence of attentional engagement effects may have been due to the disproportionate ratio of valid to invalid trials adopted by the researchers. Specifically, in the study conducted by Vogt et al. (2008) there were three times as many valid trials as there were invalid trials. In other words, the cues accurately indicated the location of the probes 75% of the time. Consequently, responses on valid trials were likely to be accelerated due to the task-relevance of attending to the cues, which would make RT differences between emotional and neutral trials difficult to detect (Fox et al., 2001; Koster, Crombez et al., 2007; Mogg & Bradley, 1998). Supporting this claim, studies which have adopted a 50:50 ratio of valid to invalid trials often report facilitated engagement of threat (e.g., Koster, Crombez, Verschuere, Van Damme et al., 2006; Koster, Crombez et al., 2007; Van Damme et al., 2004), whereas studies employing a 75:25 ratio do not (Fox et al., 2001; Fox et al., 2002; Vogt et al., 2008). By enhancing the predictive value of the cues, Vogt et al. (2008) may have reduced the task's sensitivity to detecting differential engagement effects between cue types.

To determine whether high arousing cues may facilitate attentional engagement, in addition to delaying disengagement, the current experiment adopted an equal ratio of valid to invalid trials (50:50), such that the cues did not predict the location of the probe above chance. Given that there was no performance incentive for attending to the cues, equating the proportion of valid to invalid trials served to minimise the influence of endogenous processes that may have attenuated or masked facilitated engagement effects in the study by Vogt et al. (2008). Assuming that participants are unable to ignore the cues, despite their lack of predictive value, spatial orienting observed in the current study was considered to operate exogenously (Chica, Martín-Arévalo, Botta, & Lupiánez, 2014; Jonides, 1981; Lupiáñez et al., 2004). That is, voluntary attention to the cued location should not have occurred because the probe was no more likely to have appeared in that location.

Assuming that the onset of the cues would draw attention to the cued location, a main effect of cue validity was hypothesised. Faster RTs were expected when the cue and probe appeared in the same spatial location (valid trials) compared to when the cue and probe appeared in opposite peripheries (invalid trials), thereby demonstrating that participants' attention was generally directed toward the pictures. The type of cue appearing before the probes and the length of cue exposure were hypothesised to influence the magnitude and direction of the cue validity effect, as reflected by higher order interactions involving valence, arousal, validity, and exposure duration. These interactions would indicate that attention was biased either toward or away from the different picture types during distinct stages of processing.

Predicated on the assumption that threatening stimuli hold special significance, several models predict that stimulus valence underlies the allocation of

attention to affective stimuli, with preferential processing of cues that reflect threats or danger (Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Öhman, 1996; Öhman & Mineka, 2001; Williams et al., 1988, 1997). In accordance with these theories, the cue validity effect was predicted to be potentiated on the basis of valence. Assuming that threatening stimuli facilitate attentional engagement, RTs were expected to be faster for validly cued probes preceded by threatening pictures compared to neutral and appetitive pictures. Because attentional engagement operates during early stages of information processing, speeded responses following valid threatening cues were hypothesised to occur under the brief exposure condition (100 ms). Following longer exposure to the cues (400 ms), corresponding to later stages of processing, delayed disengagement from the threatening pictures was hypothesised, as indicated by slower RTs for invalidly cued probes preceded by threatening cues relative to the neutral and appetitive cues.

Competing hypotheses were made on the basis of motivational significance theory, which predicts that early allocation of attention is determined on the basis of stimulus arousal (Bradley & Lang, 2007; Lang et al., 1997, 1998; Schimmack, 2005). In accordance with the arousal hypothesis, a larger cue validity effect was expected for the high arousing pictures compared to the low arousing pictures, independent of valence. Assuming that attentional engagement is facilitated by stimulus arousal, as opposed to threat, faster RTs were predicted for validly cued probes that were preceded by high arousing pictures compared to low arousing pictures. As observed in previous spatial cueing studies (Massar et al., 2011; Sagliano, Trojano et al., 2014; Sawada & Sato, 2015; Vogt et al., 2008), delayed disengagement from the motivationally significant stimuli was also anticipated, as

evidenced by slower responses on invalid trials employing high arousing cues relative to neutral and low arousing cues.

Although the majority of models predict that threatening or high arousing stimuli capture attention, a contrasting prediction is made by the two-stage model (Williams et al., 1988, 1997). This model assumes that attention will be directed *away* from highly threatening stimuli in non-anxious individuals. If this assumption is accurate, attentional avoidance may impede responses to validly cued probes preceded by pictures of blood injuries and mutilations, as reflected by slower RTs for trials employing HAT cues compared to the other cue types. This effect was expected to occur in the longest exposure condition (1000 ms), which allowed strategic, endogenously-mediated processes to operate.

Method

Participants

Forty-seven participants were recruited for Experiment 2.1. One participant was excluded after indicating that members of the opposite sex were not sexually appealing. Of the remaining 46 participants, 38 were female (82.61%). The age of the sample ranged between 18 and 50 years (M = 22.78, SD = 6.51). STAI-S scores varied between 21 and 68 (M = 38.54, SD = 10.42), while STAI-T scores ranged from 21 to 61 (M = 42.96, SD = 10.52).

Materials & Procedure

During this version of the SCT, the cues were exposed for 100 ms, 400 ms, and 1000 ms. The ratio of valid to invalid trials was 50:50, thereby rendering the cues irrelevant to the task. During each administration of the SCT, all pictures served as a valid and invalid cue with equal frequency and were presented equally often to

the left and right placeholder box. Within each block, there were an equal number of trials for each exposure condition.

To control for inadvertent sequencing effects, three trial sequences were constructed and reversed to produce a total of six orders, which were allocated to participants based on the order in which they completed the experiment. Cue type, exposure duration, and location were quasi-randomised for each trial sequence, as reported in the General Methodology. Prior to the commencement of each trial block, onscreen text advised participants that the cue would accurately predict the probe's location "some of the time, but not all of the time."

Results

Data Preparation

For each participant, RTs for incorrect trials were discarded (0.34% of test trials), as were responses occurring outside of 150 ms to 750 ms (0.62%). Although no outliers were detected with respect the frequency of incorrect trials, four participants exhibited an outlying proportion of responses that exceeded 750 ms, ranging between 3.51% and 5.21% of test trials. The same participants were also identified as contributing extreme outliers across several experimental conditions and were removed prior to statistical analysis. A fifth case was removed due to an outlying proportion of catch trial responses (21%). For the remaining sample, outlying responses that exceeded ± 2 *SD*s from a participant's mean RT for each experimental condition were also removed (3.33% of test trials). Statistical analyses were performed on 96.10% of the test trial data for the 41 remaining participants.

Statistical Assumptions

Prior to conducting the planned analyses, the RT data were screened for outliers and violations of relevant statistical assumptions. In accordance with the

recommendations of Tabachnick and Fidell (2012), standardised values in excess of $z = \pm 3.29$ ($p < .001$) were considered to be univariate outliers. Examination of the standardised RTs revealed an absence of outliers, which was confirmed via visual inspection of box-and-whiskers plots produced for each experimental condition.

The assumption of normality was assessed by inspecting frequency histograms and normal quantile-quantile plots. Standardised skewness and kurtosis values were also calculated and evaluated at $z = \pm 2.58$ ($p < .01$). Not surprisingly, standardised skewness values indicated that the distribution of RT data was positively skewed for several experimental conditions. Positive skewness is a common characteristic of RT distributions (Marmolejo-Ramos et al., 2015; Whelan, 2008). A logarithmic transformation was applied to the RT data and statistical analyses were repeated on the transformed values. Irrespective of whether transformed or untransformed data were analysed, the pattern of results remained unchanged. To preserve interpretability, analyses using untransformed RTs have been reported.

Using Mauchly's test ($p < .05$), the assumption of sphericity was found to be violated for the two-way interaction between arousal and exposure duration, Mauchly's $W(2) = .79$, $p = .010$. The significance of interaction remained unchanged, however, following a Greenhouse-Geisser correction. Uncorrected values have therefore been reported. The assumption of sphericity was otherwise satisfied.

Catch Trials

Responses on catch trials were low ($M = 2.34\%$ of catch trials, $SD = 3.46\%$), confirming that participants responded to the location of the probes and not the cues. Results from a one-way ANOVA, performed on the proportion of catch trial

responses, revealed no significant differences between the different cue types, $F(4, 160) = 1.43$, $MSE = 82.72$, $p = .241$, $\eta_p^2 = .03$.

Accuracy Data

The final sample exhibited near perfect accuracy on the test trials, with the proportion of correct responses ranging between 99% and 100% ($M = 99.69\%$, $SD < 0.01$). Due to the low frequency of errors, analysis of the accuracy data was unwarranted.

Reaction Time Data

Overall effects. Mean RTs obtained by the different cue types are presented in Table 5.3 for each exposure condition. These data were subjected to a 2 × 2 × 2 × 3 repeated-measures ANCOVA, with valence (threatening vs. appetitive), arousal (low vs. high), validity (valid vs. invalid), and exposure duration (100 ms vs. 400 ms vs. 1000 ms) as within-subjects factors. Mean-centered STAI-S and STAI-T scores were included as covariates and were nonsignificant, Fs < 1, indicating that RTs were not associated with state or trait anxiety. Neither state nor trait anxiety interacted with cue valence or arousal, Fs < 1. After controlling for STAI scores, a main effect of cue validity was found, $F(1, 38) = 236.41$, $MSE = 1714.32$, $p < .001$, $\eta_p^2 = .86$. Surprisingly, responses were slower on valid trials ($M = 346$ ms, $SE = 5.80$) compared to invalid trials ($M = 305$ ms, $SE = 5.14$), indicative of a *reverse* cue validity effect. The main effect of exposure duration was also significant, $F(2, 76) = 27.52$, $MSE = 1753.37$, $p < .001$, $\eta_p^2 = .42$. Faster RTs were observed in the 1000 ms exposure condition ($M = 312$ ms, $SE = 5.16$) relative to the 400 ms exposure condition ($M = 328$ ms, $SE = 6.05$), $F(1, 38) = 32.92$, $MSE = 154.75$, $p < .001$, $\eta_p^2 = .46$, which obtained faster RTs than the 100 ms exposure condition ($M = 336$ ms, $SE = 5.68$), $F(1, 38) = 6.46$, $MSE = 207.39$, $p = .030$, $\eta_p^2 = .15$. Although the main effect

of valence was nonsignificant, $F(1, 38) = 3.26$, $MSE = 541.18$, $p = .079$, $\eta_p^2 = .08$, RTs varied significantly as a function of arousal, with slower responding following the presentation of high arousing cues ($M = 332$ ms, $SE = 5.33$) compared to low arousing cues ($M = 320$ ms, $SE = 5.40$), $F(1, 38) = 70.88$, $MSE = 496.40$, $p < .001$, $\eta_p^2 = .65$. Arousal was found to interact with validity, $F(1, 38) = 36.20$, $MSE = 560.90$, $p < .001$, $\eta_p^2 = .49$, and exposure duration, $F(2, 76) = 18.80$, $MSE = 581.53$, $p < .001$, $\eta_p^2 = .33$. The interaction between validity and exposure duration was also significant, $F(2, 76) = 25.72$, $MSE = 453.61$, $p < .001$, $\eta_p^2 = .40$. These two-way interactions were subsumed, however, by a significant three-way interaction between arousal, validity, and exposure duration, $F(2, 76) = 6.36$, $MSE = 493.54$, $p = .003$, $\eta_p^2 = .14$. The three-way interaction between valence, arousal and validity was also significant, $F(1, 38) = 6.06$, $MSE = 373.38$, $p = .018$, $\eta_p^2 = .14$. All other interactions were nonsignificant, $Fs \leq 2.04$, $ps \geq .138$.

Table 5.3

Mean Response Times (ms), Standard Deviations (SD), and Cue Validity Indices (CVI) as a Function of Cue Type, Validity and Exposure Duration in Experiment 2.1.

		Exposure Duration								
		100 ms			400 ms			1000 ms		
Cue Type	Cue Validity	*M*	*SD*	CVI	*M*	*SD*	CVI	*M*	*SD*	CVI
Low Arousing Threatening	Valid	344	39	-23	333	42	-32	325	41	-26
	Invalid	321	40		301	44		300	34	
Low Arousing Appetitive	Valid	347	42	-30	337	47	-44	326	49	-34
	Invalid	317	41		293	38		292	34	
High Arousing Threatening	Valid	364	44	-39	376	57	-68	337	38	-47
	Invalid	325	39		308	36		290	34	
High Arousing Appetitive	Valid	354	42	-36	376	58	-73	332	40	-35
	Invalid	318	37		303	37		297	44	
Neutral	Valid	347	37	-30	323	34	-29	314	36	-22
	Invalid	317	33		293	35		292	35	

To follow-up the significant Arousal × Validity × Exposure interaction, separate ANCOVAs were conducted at each level of exposure duration, with arousal and validity as within-subjects factors. To maintain consistency with the omnibus analysis, STAI-S and STAI-T scores were included as covariates and were nonsignificant for each exposure condition, Fs ≤ 2.23, ps $\geq .144$. If interactions between arousal and validity were significant, cue validity indices ($RT_{\text{Invalid Cue}} - RT_{\text{Valid Cue}}$) were calculated as a general measure of attention for the low and high arousing cues. Because valence was absent from the higher-order interaction, CVIs were averaged over the threatening and appetitive cue types. To determine the relative effects of arousal, CVIs for the neutral cues were subtracted from CVIs calculated for the low and high arousing cue types. Thus, values greater than zero reflected enhanced attention for that cue type compared to the neutral cues. Conversely, values less than zero demonstrated that attention oriented more readily to the neutral cues. The relevant analyses are progressed over the subsequent pages. CVIs obtained by the low and high arousing cues are plotted in Figure 5.4 according to exposure condition.

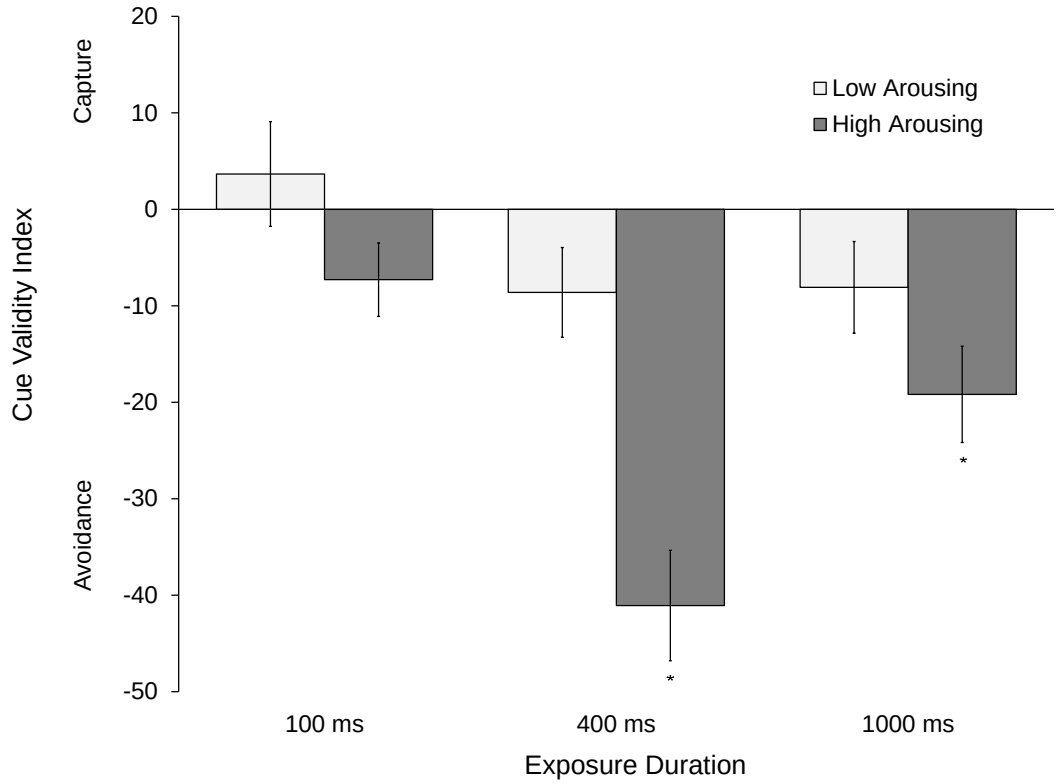

Figure 5.4. Cue validity indices as a function of cue arousal and exposure duration (Experiment 2.1). Zero = no difference from the neutral cues. Error bars = standard errors. * denotes significant difference from zero, $p < .05$.

100 ms. A reverse cue validity effect was observed when the cues were presented for 100 ms, with slower responding on valid trials (M = 352 ms, SE = 5.93) compared to invalid trials (M = 320 ms, SE = 5.79), $F(1, 38) = 128.27$, MSE = 330.28, $p < .001$, $\eta_p^2 = .77$. A significant effect of arousal revealed that RTs were slower following the high arousing cues (M = 340 ms, SE = 5.80) compared to low arousing cues (M = 332 ms, SE = 5.69), $F(4, 152) = 22.41$, MSE = 113.24, $p < .001$, $\eta_p^2 = .37$. Importantly, the interaction between arousal and validity was also significant, $F(1, 38) = 4.27$, MSE = 288.19, $p = .046$, $\eta_p^2 = .10$, demonstrating that attentional orienting to the cues varied as a function of arousal.

Cue validity indices. As can be seen in Figure 5.4, when the cues were presented for 100 ms, CVIs were larger for the low arousing cues (M = 4, SE = 5.43) than the high arousing cues (M = -7, SE = 3.81), $F(1, 38) = 4.27$, MSE = 576.38, p = .046, $\eta_p^2 = .10$. This result indicates that attention oriented more readily to the low arousing pictures than the high arousing pictures. Single sample t-tests revealed that CVIs did not differ significantly from zero for the low arousing cues, $t < 1$, or the high arousing cues, $t(40) = 1.92$, $p = .062$, $d = 0.30$, suggesting that attentional orienting to the affective pictures was consistent with attention for the neutral pictures.

Attentional indices. To examine whether the specific components of spatial attention were biased by arousal during the first 100 ms of stimulus processing, engagement and disengagement indices were calculated for the low and high arousing cue types. Engagement indices were calculated from the valid trials, with RTs to probes preceded by motivationally significant pictures subtracted from RTs to probes preceded by neutral pictures. Values greater than zero indicated that attention to the cues was facilitated, whereas values less than zero reflected avoidance. Disengagement indices were calculated from the invalid trials, with RTs to probes following neutral pictures subtracted from RTs to probes preceded by motivationally significant pictures. Positive values demonstrated that disengagement was delayed, whereas negative values indicated speeded disengagement. For both indices, a value of zero reflected no difference from the neutral stimuli. Because valence was absent from the higher-order interaction, the engagement and disengagement indices were averaged over this factor. The attentional indices are plotted in Figure 5.5 for each exposure condition. At 100 ms post-stimulus onset, single sample t-tests revealed that engagement indices obtained by the high arousing

cues (M = -12, SD = 18) were significantly below zero, $t(40) = 4.23$, $p < .001$, d = .66, indicative of attentional avoidance. All other comparisons in the 100 ms exposure condition were nonsignificant, ts ≤ 1.70, ps $\geq .097$.

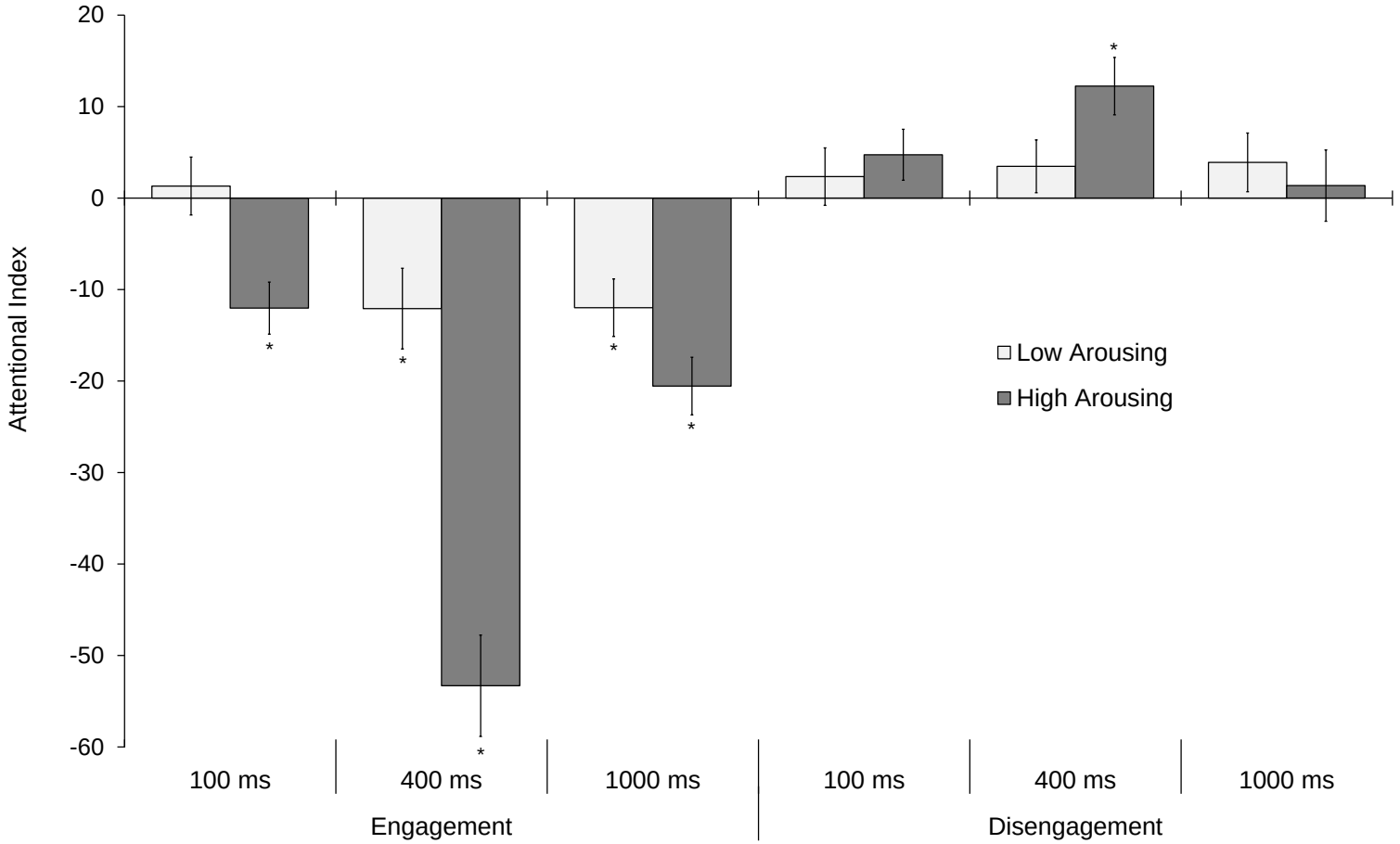

Figure 5.5. Attentional engagement and disengagement indices as a function of cue arousal and exposure duration (Experiment 2.1). Zero = no difference from the neutral cues. Error bars = standard errors. * denotes significant difference from zero, $p < .05$.

400 ms. When the cues were exposed for 400 ms, a reverse cue validity effect was observed, $F(1, 38) = 199.99$, $MSE = 603.02$, $p < .001$, $\eta_p^2 = .84$, characterised by slower RTs on valid trials ($M = 355$ ms, $SE = 7.01$) relative to invalid trials ($M = 301$ ms, $SE = 5.62$). There was also a significant effect of arousal, $F(1, 38) = 54.45$, $MSE = 470.40$, $p < .001$, $\eta_p^2 = .59$. Slower responding was observed when the probes were cued by high arousing pictures ($M = 340$ ms, $SE = 6.47$) compared to low arousing pictures ($M = 316$ ms, $SE = 6.10$), $F(1, 38) = 54.45$, $MSE = 470.40$, $p < .001$, $\eta_p^2 = .59$. The interaction between arousal and validity was also significant, $F(1, 38) = 38.65$, $MSE = 279.45$, $p < .001$, $\eta_p^2 = .50$, indicating differential cueing effects on the basis of arousal.

Cue validity indices. Analysis of the CVIs calculated for the 400 ms exposure condition revealed an effect of arousal, $F(1, 38) = 38.65$, $MSE = 558.91$, $p < .001$, $\eta_p^2 = .50$. As shown in Figure 5.4, CVIs were larger for the low arousing cues ($M = -9$, $SE = 4.56$) than the high arousing cues ($M = -41$, $SE = 5.72$), demonstrating that attentional orienting favoured the less arousing pictures. Comparisons against zero showed that CVIs for the high arousing cues were significantly below zero, $t(40) = 7.36$, $p < .001$, $d = 1.15$, indicating that attention was directed away from the motivationally significant pictures. Although the low arousing cues also obtained a negative CVI, this was not significantly different from zero, $t(40) = 1.89$, $p = .066$, $d = 0.30$.

Attentional bias indices. With respect to the specific components of attentional orienting, engagement indices were significantly below zero for both the low ($M = -12$, $SD = 28$) and high arousing cues ($M = -53$, $SD = 35$), with $t(40) = 2.74$, $p = .009$, $d = 0.43$, and $t(40) = 9.62$, $p < .001$, $d = 1.50$, respectively. Consistent with attentional avoidance, these results suggest that participants' attention was more readily engaged

by the neutral cues at 400 ms post-stimulus onset. A post-hoc comparison showed stronger avoidance of the high arousing cues than the low arousing cues, $t(40) = 7.93$, $p < .001$, $d = 1.26$. Disengagement indices were significantly greater than zero for the high arousing cues ($M = 12$, $SD = 20$), $t(40) = 3.89$, $p < .001$, $d = 0.61$, indicating that attention was slower to disengage from the more arousing pictures compared to the neutral pictures. Disengagement indices obtained by the low arousing cues were not significantly different from zero ($M = 3$, $SD = 18$), $t(40) = 1.20$, $p = .236$, $d = 0.19$.

1000 ms. Consistent with the briefer exposure conditions, a reverse cue validity effect was also observed when the cues were shown for 1000 ms, with slower responding on valid trials ($M = 327$ ms, $SE = 5.56$) relative to invalid trials ($M = 294$ ms, $SE = 4.90$), $F(1, 38) = 136.03$, $MSE = 377.48$, $p < .001$, $\eta_p^2 = .78$. Although the effect of arousal was nonsignificant, $F(1, 38) = 1.52$, $MSE = 246.09$, $p = .226$, $\eta_p^2 = .04$, a significant Arousal × Validity interaction emerged, $F(1, 38) = 6.12$, $MSE = 206.35$, $p = .018$, $\eta_p^2 = .14$, demonstrating that attentional orienting was affected by cue arousal during late stages of processing.

Cue validity indices. CVIs obtained in the 1000 ms exposure condition were larger for the low arousing cues ($M = -8$, $SE = 4.75$) than the high arousing cues ($M = -19$, $SE = 4.99$), $F(1, 38) = 6.12$, $MSE = 825.40$, $p = .018$, $\eta_p^2 = .13$, suggesting that participants directed their attention away from pictures rated higher in arousal. Comparisons against zero showed that CVIs for the high arousing cues were significantly less than zero, $t(40) = 3.91$, $p < .001$, $d = 0.61$, further indicating that attention avoided the more arousing pictures. In contrast, CVIs obtained for the low arousing cues did not vary significantly from zero, $t(40) = 1.73$, $p = .091$, $d = 0.27$.

Attentional bias indices. Reflective of attentional avoidance, engagement indices were significantly below zero for the high arousing cues ($M = -21$, $SD = 20$),

$t(40) = 6.53$, $p < .001$, $d = 1.02$, and the low arousing cues ($M = -12$, $SD = 20$), $t(40) = 3.81$, $p < .001$, $d = 0.59$. A post-hoc comparison revealed that engagement indices were significantly lower for the high arousing cues than low arousing cues, $t(40) = 2.44$, $p < .019$, $d = 0.38$, indicating stronger avoidance of the more arousing pictures. Disengagement indices did not vary significantly from zero, ts ≤ 1.22, ps $\geq .231$.

The three-way interaction between valence, arousal, and validity revealed by the omnibus ANCOVA was decomposed by calculating CVIs for each cue type, while averaging over exposure duration. After subtracting CVIs obtained by the neutral cues, CVIs calculated for the motivationally significant pictures were analysed using a 2 × 2 ANCOVA to determine the effects of valence (threatening vs. appetitive) and arousal (low vs. high) on attention during the first 1000 ms of stimulus processing. Results showed a main effect of arousal, $F(1, 38) = 36.20$, $MSE = 373.93$, $p < .001$, $\eta_p^2 = .49$, which was qualified by a significant Valence × Arousal interaction, $F(1, 38) = 6.06$, $MSE = 248.92$, $p = .018$, $\eta_p^2 = .14$, as depicted in Figure 5.6. The effect main effect of valence was nonsignificant, $F(1, 38) = 1.37$, $MSE = 296.37$, $p = .250$, $\eta_p^2 = .04$.

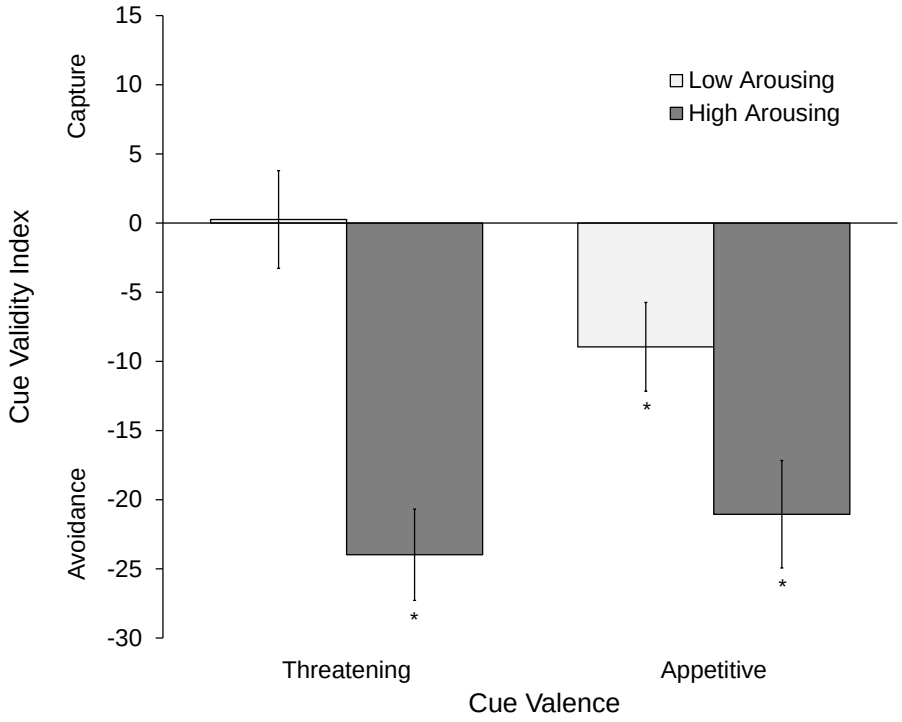

Figure 5.6. Cue validity indices as a function of valence and arousal, averaged over exposure duration (Experiment 2.1). Zero = no difference from the neutral pictures. Error bars = standard errors. * denotes significant difference from zero, $p < .05$.

To clarify the combined effect of valence and arousal on the CVIs, tests of simple effects were performed to detect significant differences between the low and high arousing cues at each level of valence. As can be seen in Figure 5.6, when the probes were cued by threatening pictures, CVIs were smaller for the high arousing cues (M = -24, SE = 3.30) than the low arousing cues (M = 0, SE = 3.53), $F(1, 38)$ = 36.12, MSE = 333.45, $p < .001$, $\eta_p^2 = .49$. The effect of arousal was also significant when the probes were preceded by appetitive pictures, $F(1, 38) = 10.38$, MSE = 289.41, $p = .003$, $\eta_p^2 = .22$. Although CVIs were again smaller for the high arousing cues (M = -21, SE = 3.89) relative to the low arousing cues (M = -9, SE = 3.21), the effect of arousal on attention for the appetitive cues was weaker compared to that observed for the threatening pictures. Single sample t-tests showed that CVIs were

significantly below zero for the HAT cues, $t(40) = 7.40$, $p < .001$, $d = 1.16$, the HAA cues, $t(40) = 5.51$, $p < .001$, $d = 0.86$, and the LAA cues, $t(40) = 2.84$, $p = .007$, $d = 0.44$, indicating that attention oriented more readily towards the neutral cues. In contrast to the other cue types, CVIs for the LAT cues did not vary significantly from zero, $t(40) = 0.08$, $p = .941$, $d = 0.01$.

Attentional bias indices. To clarify how the specific components of attention were affected by the Valence × Arousal interaction, engagement and disengagement indices were calculated for each type and averaged over exposure duration. As shown in Figure 5.7, all of the motivationally significant cue types obtained negative engagement indices that were significantly below zero: LAT ($M = -6$, $SD = 14$), $t(40) = 2.95$, $p = .005$, $d = 0.46$; LAA ($M = -9$, $SD = 16$), $t(40) = 3.47$, $p = .001$, $d = 0.54$; HAT ($M = -31$, $SD = 20$), $t(40) = 9.86$, $p < .001$, $d = 1.54$; HAA ($M = -26$, $SD = 20$), $t(40) = 8.44$, $p < .001$, $d = 1.32$. These results suggest that attention tended to avoid the motivationally significant cues relative to the neutral cues. Indices of delayed disengagement were significantly greater than zero for the LAT cues ($M = 7$, $SD = 16$), $t(40) = 2.60$, $p = .013$, $d = 0.41$, the HAT cues ($M = 7$, $SD = 14$), $t(40) = 3.16$, $p = .003$, $d = 0.49$, and the HAA cues ($M = 20$, $SD = 27$), $t(40) = 2.12$, $p = .040$, $d = 0.33$, indicating that attention was slower to disengage from these pictures compared to the neutral pictures. In contrast to the other cue types, disengagement indices for the LAA cues ($M = 0$, $SD = 13$) did not vary significantly from zero, $t < 1$.

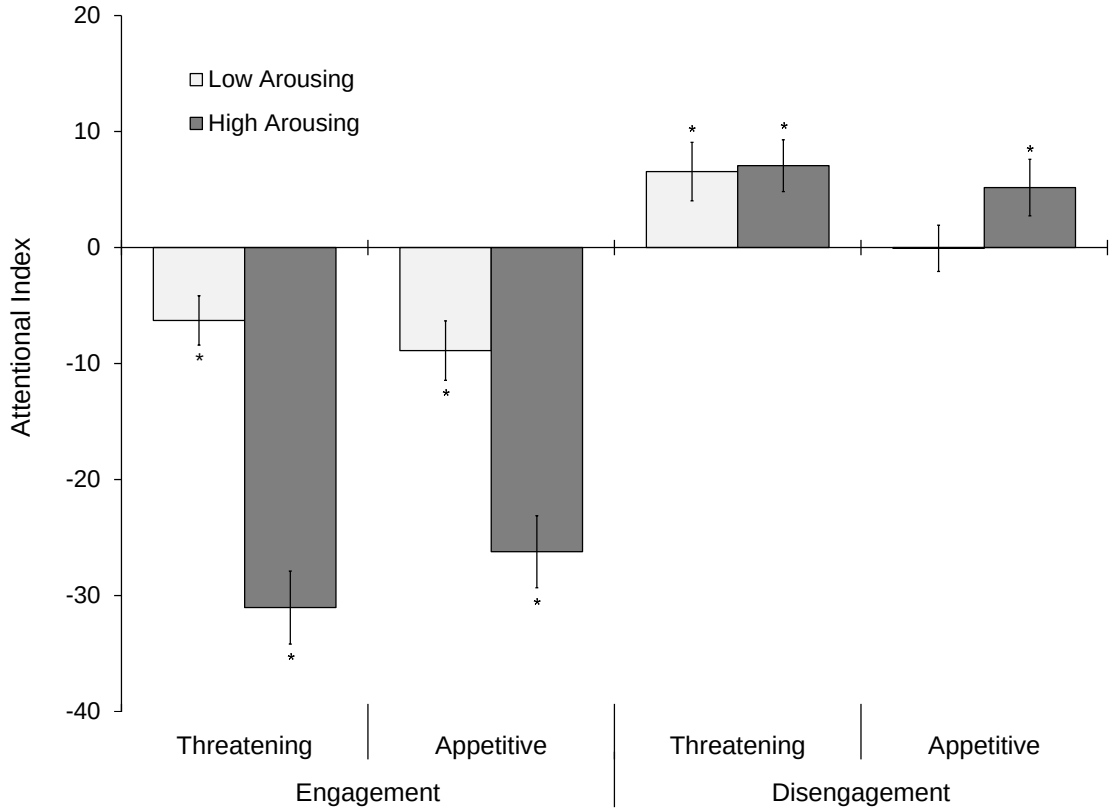

Figure 5.7. Attentional engagement and disengagement indices as a function of cue valence and arousal, averaged over exposure duration (Experiment 2.1). Zero = no difference from the neutral cues. Error bars = standard errors. * denotes significant difference from zero, $p < .05$.

Discussion

Experiment 2.1 adopted an equal ratio of valid to invalid trials, thereby rendering the cues task-irrelevant and yielding a measure of exogenous orienting. Surprisingly, results revealed a reverse cue validity effect, with *slower* RTs for probes preceded by valid cues compared to invalid cues. Within each exposure condition, negative CVIs were recorded for all cue types, suggesting that participants' attention was consistently directed away from the pictures at the time of probe onset. Because the cues did not reliably predict the location of the probes, it is possible that attention shifted away from the pictures to minimise irrelevant processing and enhance task

efficiency. The reverse cue validity effect may also reflect IoR, whereby attention is inhibited from returning to an already attended to location (Klein, 2000; Posner & Cohen, 1984). If participants' attention was inhibited from returning to the cued location, this would explain why RTs were comparatively slower for valid trials relative to invalid trials. IoR assumes, however, that participants' attention engaged and processed the cues, but disengaged prior to probe onset (Klein, 2000; Posner & Cohen, 1984). That is, IoR only occurs after attention has shifted to and processed that location. Furthermore, IoR is typically observed at SOAs greater than ~ 300 ms (Klein, 2000; Samuel & Kat, 2003).

A main effect of cue arousal revealed that responses to the probes were generally slower following the presentation of high arousing pictures compared to low arousing pictures. Given this effect occurred independently of cue validity, the presence of arousing content appears to have produced interference unrelated to spatial attention. Non-spatial interference cannot explain, however, the significant three-way interaction between arousal, validity, and exposure duration. This higher-order interaction suggested that cue arousal influenced the orienting of spatial attention and that this effect varied across exposure conditions.

Despite predictions that motivational significance would facilitate attention to the cues during early stages of processing, attentional orienting appeared to favour the low arousing cues in the 100 ms condition, as indicated by larger CVIs for pictures depicting interpersonal aggression and nurturance of offspring compared to the high arousing pictures of mutilated bodies and erotica. In the presence of high arousing cues, IoR may function to preserve task-efficiency by inhibiting irrelevant processing of provocative material. Maintaining consistency with previous spatial cueing studies (Koster, Crombez, Verschuere, Van Damme et al., 2006; Koster, Crombez et al., 2007;

Sagliano, Trojano et al., 2014), attentional engagement and disengagement indices were calculated for the low and high arousing cues to determine which components of spatial attention were affected by arousal in the 100 ms exposure condition. Contrary to the assumptions of motivational significance theory (Bradley & Lang, 2007; Lang et al., 1997, 1998), engagement indices obtained for the high arousing cues were significantly below zero. Previously interpreted as a marker of attentional avoidance (Koster, Crombez, Verschuere, Van Damme et al., 2006), a negative engagement index suggests that participants' attention was more readily engaged by the neutral pictures than the pictures of mutilated bodies and erotica. There was no evidence of delayed disengagement in the 100 ms exposure condition, which is not surprising given that attentional disengagement is assumed to operate during later stages of processing (i.e., > 100 ms; Cisler & Koster, 2010). Attentional indices obtained for the low arousing pictures were also nonsignificant, indicating that attentional allocation to pictures of interpersonal aggression and infant rearing was comparable to that of the neutral pictures during early stages of stimulus processing.

In the 400 ms condition, corresponding to later stages of processing, analysis of the CVIs revealed that the high arousing pictures continued to elicit a reverse cue validity effect. Given that negative CVIs are considered to be reflective of IoR, this finding suggests that attention did not return as readily to spatial locations previously occupied by pictures of mutilated bodies and erotica compared to the less arousing stimuli. Indices of attentional engagement were significantly below zero for both the low and high arousing cues, indicating attentional avoidance of the affective pictures. A post-hoc comparison revealed that avoidance was stronger for pictures rated higher in arousal. Interestingly, the high arousing cues also obtained disengagement indices that were significantly greater than zero. Assuming that RTs on invalid trials reflect

the costs of having to disengage and shift attention away from cued locations, these data suggest that attention was slower to disengage from the pictures of mutilations and erotica compared to the neutral pictures. This finding supports predictions that delayed disengagement from affective stimuli is determined by motivational significance, as indexed by arousal, and converges with previous spatial cueing studies (Massar et al., 2011; Sagliano, Trojano et al., 2014; Vogt et al., 2008).

Phenomenologically, delayed disengagement and avoidance are conflicting processes (Cisler et al., 2009). The negative engagement and positive disengagement indices observed for the high arousing cues in the 400 ms exposure condition are therefore difficult to interpret in terms of spatial attention. Because RTs were slower following the high arousing pictures on both valid and invalid trials, it is possible that results from the 400 ms exposure condition were influenced by non-spatial interference that is sensitive to stimulus arousal. That is, the provocative nature of the high arousing cues may have produced task-irrelevant processing of their emotional content at the cost of slower responses to the probes.

Following 1000 ms of cue exposure, a significant Arousal × Validity interaction demonstrated that the motivationally significant cues continued to influence spatial attention during late stages of processing, when strategic processes are likely to operate. Replicating results from the briefer exposure conditions, the reverse cue validity effect was larger for high arousing pictures than low arousing pictures. Because the cues did not accurately predict the location of the probes above chance, and were therefore irrelevant to the task, attention was expected to shift away from the cues during prolonged exposure. Consistent with IoR, the negative CVIs observed in the 1000 ms exposure condition suggest that attention was inhibited from returning to locations cued by motivationally significant pictures. As indicated by

negative engagement indices, attention appeared to avoid the motivationally significant stimuli, with stronger avoidance of pictures rated as more arousing. There was no evidence of delayed disengagement in the 1000 ms exposure condition.

The omnibus analysis also revealed a significant Valence × Arousal × Validity interaction. The nature of the interaction was such that stimulus arousal had a stronger effect on attention for the threatening pictures than the appetitive pictures. As depicted in Figure 5.6, when the probes followed threatening pictures, attention was slower to return to locations cued by pictures of mutilations and blood injuries relative to the less arousing pictures depicting interpersonal aggression. A significant, albeit smaller, effect of arousal was also observed when the probes were cued by appetitive pictures, with delayed reorienting to locations of erotic pictures compared to pictures of infant rearing. These findings suggest that IoR from motivationally significant stimuli is augmented by a combined effect of valence and arousal during the first 1000 ms of stimulus processing.

Potentiation of the reverse cue validity effect on the basis of valence and arousal can be interpreted in terms of endogenous processes that function to regulate mood and affect by limiting exposure to provocative stimuli. This explanation is consistent with the two-stage model (Williams et al., 1997), which assumes that non-anxious individuals direct attentional resources away from high threat stimuli. Participants may have intentionally directed their attention away from the HAT stimuli to minimise processing the distressing content. Consistent with this interpretation, Ellenbogen et al. (2002) demonstrated that attentional avoidance of threatening pictures is associated with reduced cortisol secretion, and may therefore function to regulate stress reactions. In contrast to the HAT pictures, attention may have returned

more readily to the LAT pictures, depicting interpersonal aggression, due to their capacity to signal the presence of danger without evoking intense affective reactions.

Attentional avoidance of HAT pictures is also consistent with findings from previous spatial cueing studies. In their sample of non-anxious participants, Koster, Crombez et al. (2007; Experiment 3) observed reduced attentional orienting to highly threatening pictures, including pictures of mutilated bodies, compared to neutral pictures following 500 ms of cue exposure. Yiend and Mathews (2001) reported similar results in low anxious participants, with slower responses to probes replacing threatening pictures relative to non-threatening pictures. Waters et al. (2007) also reported potentiated IoR for threatening pictures in low anxious participants. Considered together, the current results demonstrate that attentional avoidance of threatening stimuli might be potentiated on the basis of arousal, and is not restricted to extremely low anxious individuals.

IoR was not limited to the HAT pictures. As can be seen in Figure 5.6, pictures depicting heterosexual erotica also obtained a negative CVI, which was lower than that of the less arousing appetitive pictures. Avoidance of the high arousing appetitive pictures was not expected and is contrary to the assumptions of the motivational model of emotion (Lang et al., 1997, 1998), which predicts greater attentional allocation to stimuli that are symbolic of reproductive opportunities. The negative engagement and positive disengagement indices obtained by the HAA cues indicate that responding was delayed on both valid and invalid trials employing these stimuli, leading to opposing interpretations of avoidance and delayed disengagement. These data are perhaps better explained by interference effects unrelated to the orienting of spatial attention. Specifically, the erotic pictures may have prompted more elaborative processing compared to the neutral and low arousing pictures. This interpretation is

supported by ERP studies that have demonstrated enhanced neural processing of sexually explicit stimuli compared to threatening and other positively valenced material (Briggs & Martin, 2008, 2009; Feng et al., 2012; Schupp, Junghöfer, Weike, & Hamm, 2004).

Because the cues did not predict the location of the probes above chance, participants' attention may have shifted away from the cued location before the onset of the probe. Indeed, non-emotional variants of the SCT have demonstrated attention can shift away from non-predictive cues at around 300 ms post-stimulus onset, resulting in slower RTs for valid trials than invalid trials, consistent with IoR (Posner & Cohen, 1984; Prinzmetal, Zvinyatskovskiy, Gutierrez, & Dilem, 2009). In contrast, when the cues accurately predict the probe's location on most trials, endogenous processes may operate to maintain attention on the cued location, even as the SOA between the cue and probe increases (Posner, Cohen, & Rafal, 1982; Warner, Joula, & Koshino, 1990).

Experiment 2.2

In non-affective cueing studies that have manipulated the ratio of valid to invalid trials, attentional orienting has shown to be sensitive to the proportion of valid cues (Landau, Prinzmetal, Robertson, & Silver, 2009; Prinzmetal, McCool, & Park, 2005). Although RTs observed in these studies were faster for valid relative to invalid trials regardless of the cues' predictive value, cueing effects were enhanced when the cues accurately indicated the probe location on the majority of trials. These findings demonstrate that predictive cues are more likely to attract and sustain attention than non-predictive cues. According to Prinzmetal et al. (2005), when cues are informative, and therefore relevant to the task, their perceptual representations are enhanced by endogenous attention. In contrast, perceptual processing is unaffected when the cues are non-predictive.

In the current experiment, the ratio of valid to invalid trials was increased to 75:25. That is, the cues accurately indicated the location of the probe on 75% of trials. Because of the cues' predictive value, efficiency on the task could be enhanced by volitionally attending to the cued location, promoting the recruitment of top-down, endogenous processes (Lupiáñez et al., 2004). Under these conditions, voluntary attentional processes were predicted to enhance attention for the cues, thereby speeding RTs on valid trials and slowing RTs on invalid trials (Prinzmetal et al., 2005).

Given the predictive value of the cues, it was hypothesised that endogenous processes would enhance attention for the pictures, resulting in faster RTs for valid trials compared to invalid trials. Adopting the same hypotheses as the previous experiment, the cue validity effect was predicted to vary according to the affective qualities of the cues and the time-course of attentional processing, as demonstrated by

a significant four-way interaction between valence, arousal, validity, and exposure duration. In accordance with threat-specific models (Beck & Clark, 1997; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Öhman, 1996; Öhman & Mineka, 2001; Williams et al., 1988, 1997), the cue validity effect was predicted to be potentiated for threatening pictures relative to appetitive and neutral pictures. In the 100 ms exposure condition, the threatening pictures were hypothesised to facilitate attentional engagement, as indicated by faster RTs for validly cued probes preceded by threatening cues compared to neutral cues. Delayed disengagement from the threatening pictures was expected when the cues were exposed for 400 ms, with RTs slowed on invalid trials employing threatening cues compared to neutral cues. Finally, as predicted by the two-stage model (Williams et al., 1988, 1997), attention was hypothesised to avoid the pictures of blood injuries and mutilations in the 1000 ms condition, as demonstrated by slower RTs on valid trials following the presentation of HAT pictures relative to neutral pictures.

In contrast to the threat-superiority hypothesis, the motivational model of emotion (Lang et al., 1997, 1998) predicted that the cue validity effect would be enhanced on the basis of arousal, with facilitated engagement and delayed disengagement observed for the high arousing cues. When compared to the neutral cues, the high arousing pictures were hypothesised to facilitate faster RTs on valid trials in the 100 ms exposure condition, and slow RTs on invalid trials in the 400 ms exposure condition.

Method

Participants

A sample of 44 participants was recruited for Experiment 2.2, which included 34 females (77.27%). The age of the participants ranged between 18 and 63 years (*M* =

27.43 years, *SD* = 10.42). Scores on the trait scale of the STAI (Spielberger et al., 1983) ranged from 21 to 78 (*M* = 37.32, *SD* = 11.37), whereas state anxiety scores ranged from 20 to 64 (*M* = 35.19, *SD* = 9.62). All participants reported heterosexual orientation.

Materials & Procedure

To increase the proportion of valid to invalid trials to 75:25, each picture served as a cue on three times as many valid trials relative to invalid trials. Six trial sequences were developed to ensure that, across the sample, each picture was presented equally often to the left and right periphery, at each exposure duration, while serving as both a valid and invalid cue. To minimise possible sequencing effects, these orders were reversed to generate a total of 12 trial sequences that were administered with comparable frequency across the sample. Within each trial sequence, cue type, exposure duration, and location were quasi-randomised, as detailed in the General Methodology. Participants were assigned a trial sequence according to the order in which they completed the experiment. At the commencement of each block, they were informed that the cue would accurately predict the location of the probe on "*most*, but not all trials." With the exception of increasing the ratio of valid to invalid trials, Experiment 2.2 adopted the same materials and procedures used in the previous experiment.

Results

Data Preparation

Trials corresponding with incorrect responses were discarded (0.35%). For correct trials, RTs faster than 150 ms latencies and slower than 750 ms were also removed (0.92%). Three participants were found to have an outlying proportion of test trials removed due to slow responding, ranging between 4.21% and 5.90%. Because

these participants were found to contribute extreme outliers across several experimental conditions, their data were excluded from statistical analysis. RTs occurring outside of ± 2 *SD*s from the participant's mean for each experimental condition were also removed (3.09% of test trials). Statistical analyses were performed on 95.92% of the data obtained from the remaining 41 participants.

Statistical Assumptions

A parallel approach to that used in Experiment 2.1 was applied to screen for outliers and violations of statistical assumptions. No outliers were identified within the final data set. RT distributions were positively skewed for several experimental conditions, as indicated by standardised skewness values exceeding $z = 2.58$ ($p < .01$). Despite minor violations to the assumption of normality, however, analyses performed using raw and log transformed RTs produced consistent results. The untransformed data have therefore been reported. Mauchley's test revealed that the assumption of sphericity was violated for the main effect of exposure duration, Mauchly's $W(2) = .76$, $p = .007$. The significance of this effect remained unchanged, however, following a Greenhouse-Geisser correction.

Catch Trials

Data from one participant revealed responses to all 24 catch trials and were discarded. On average, the retained participants ($N = 40$) responded to 5.25% of the catch trials ($SD = 5.17$). The low frequency of catch trial responses confirms that all remaining participants completed the SCT as intended, by responding to the location of the probes as opposed to the cues. The results of a one-way ANOVA revealed no significant differences between the different cue types with respect to the proportion of catch trial responses, $F(4, 156) = 1.53$, $MSE = 117.19$, $p = .195$, $\eta_p^2 = .04$.

Accuracy Data

The number of errors made on the test trials was low. The proportion of correct responses ranged between 97% and 100% (M = 99.38%, SD = 0.01). Due to the low frequency of errors, analysis of the accuracy data did not yield any meaningful results and has not been reported.

Reaction Time Data

Overall effects. Descriptive statistics for each experimental condition are reported in Table 5.4. These data were subjected to a 2 × 2 × 2 × 3 repeated-measures ANCOVA, with valence (threatening vs. appetitive), arousal (low vs. high), validity (valid vs. invalid) and exposure duration (100 ms vs. 400 ms vs. 1000 ms) as within-subjects factors. To control for individual differences in state and trait anxiety, mean-centered STAI-S and STAI-T scores were included as covariates.

Table 5.4

Mean Response Times (ms), Standard Deviations (SD), and Cue Validity Indices (CVI) as a Function of Cue Type, Validity and Exposure Duration in Experiment 2.2.

		Exposure Duration								
		100 ms			400 ms			1000 ms		
Cue Type	Cue Validity	*M*	*SD*	CVI	*M*	*SD*	CVI	*M*	*SD*	CVI
Low Arousing Threatening	Valid	339	43	12	334	43	8	329	43	7
	Invalid	351	53		342	56		336	58	
Low Arousing Appetitive	Valid	343	41	1	328	38	-3	323	42	3
	Invalid	344	50		325	50		325	57	
High Arousing Threatening	Valid	355	51	-6	360	55	-23	345	48	-22
	Invalid	349	49		337	55		323	55	
High Arousing Appetitive	Valid	358	60	-3	354	57	1	348	56	-11
	Invalid	355	50		355	64		337	73	
Neutral	Valid	344	45	-5	322	40	2	320	40	2
	Invalid	339	51		324	50		322	55	

The results of the four-way ANCOVA revealed that RTs were unaffected by state or trait anxiety, *F*s < 1. Scores on the STAI-S and STAI-T did not interact significantly with cue valence or arousal, *F*s ≤ 2.19. Contrary to predictions, the main effect of validity was nonsignificant, $F(1, 37) = 1.17$, $MSE = 1837.54$, $p = .286$, $\eta_p^2 = .03$, indicating that RTs were unaffected by whether the probes were preceded by a valid ($M = 343$ ms, $SE = 6.73$) or invalid cue ($M = 340$ ms, $SE = 7.71$). A significant effect of exposure condition demonstrated that response latencies varied as a function of exposure duration, $F(2, 74) = 11.74$, $MSE = 1752.34$, $p < .001$, $\eta_p^2 = .24$. Follow-up tests confirmed that RTs were faster in the 1000 ms exposure condition ($M = 333$ ms, $SE = 7.72$) relative to the 400 ms exposure condition ($M = 342$ ms, $SE = 7.19$), $F(1, 37) = 7.59$, $MSE = 190.44$, $p = .018$, $\eta_p^2 = .17$, which in turn were faster than RTs in the 100 ms exposure condition ($M = 349$ ms, $SE = 7.15$), $F(1, 37) = 7.85$, $MSE = 144.06$, $p = .016$, $\eta_p^2 = .18$.

After controlling for STAI scores, a main effect of cue arousal was found, $F(1, 37) = 54.37$, $MSE = 730.02$, $p < .001$, $\eta_p^2 = .60$, which was qualified by a significant Arousal × Exposure Duration interaction, $F(2, 74) = 3.73$, $MSE = 611.34$, $p = .029$, $\eta_p^2 = .09$. The two-way interaction was followed-up by examining the effect of arousal within each exposure condition. As can be seen in Figure 5.8, when the cues were exposed for 100 ms, RTs were significantly slower for probes preceded by high arousing cues ($M = 354$ ms, $SE = 7.59$) than low arousing cues ($M = 344$ ms, $SE = 6.90$), $F(1, 37) = 15.08$, $MSE = 121.08$, $p < .001$, $\eta_p^2 = .29$. An even stronger effect of arousal was found in the 400 ms exposure condition, $F(1, 37) = 36.83$, $MSE = 196.52$, $p < .001$, $\eta_p^2 = .50$. Again, responses were slower following high arousing cues ($M = 351$ ms, $SE = 8.10$) than low arousing cues ($M = 332$ ms, $SE = 6.53$). When the cues were shown for 1000 ms, RTs continued to be slowed by the

high arousing cues (*M* = 338 ms, *SE* = 8.31) relative to the low arousing cues (*M* = 328 ms, *SE* = 7.37), $F(1, 37) = 11.73$, $MSE = 170.58$, $p = .002$, $\eta_p^2 = .24$, albeit the effect of arousal was less pronounced compared to the 400 ms exposure condition.

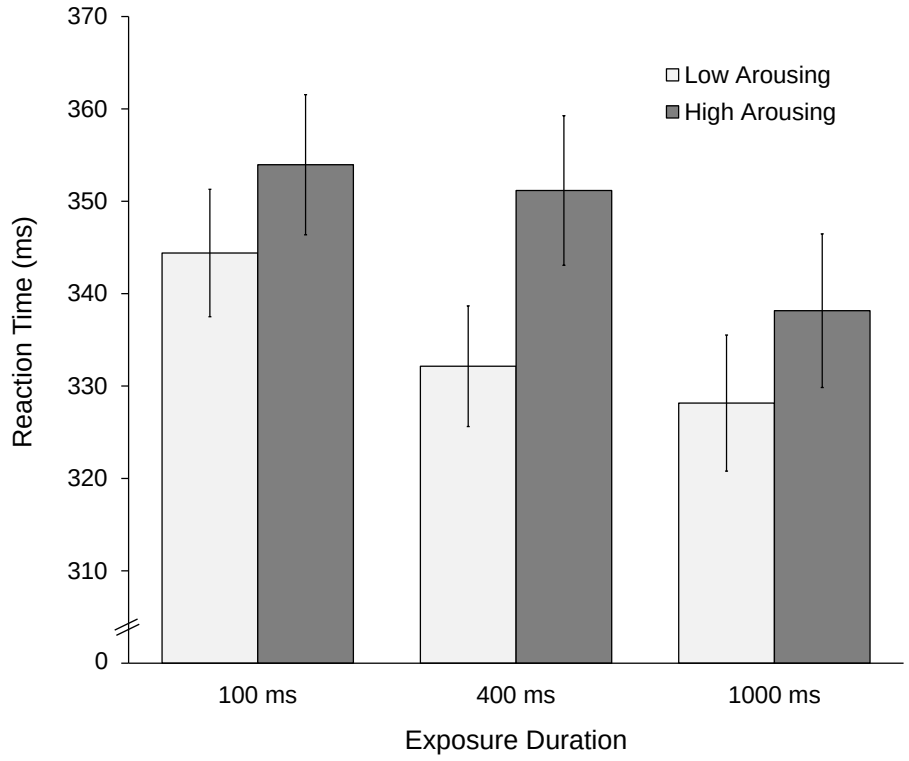

Figure 5.8. Reaction times (ms) for probes preceded by low and high arousing cues as a function of exposure condition (Experiment 2.2). Error bars = standard errors.

Although the omnibus ANCOVA revealed that the main effect of valence was nonsignificant, $F < 1$, a significant Valence × Arousal interaction did emerge, $F(1, 37) = 11.62$, $MSE = 951.95$, $p = .002$, $\eta_p^2 = .24$. Arousal was also found to interact with validity, $F(1, 37) = 25.91$, $MSE = 544.73$, $p < .001$, $\eta_p^2 = .41$. These two-way interactions were subsumed, however, by a significant three-way interaction between valence, arousal, and validity, $F(1, 37) = 17.65$, $MSE = 397.80$, $p < .001$, $\eta_p^2 = .32$. All other interactions were nonsignificant, Fs ≤ 1.36, ps $\geq .264$.

Cue validity indices. Prior to examining the significant Valence × Arousal × Validity interaction, CVIs were calculated for each cue type ($RT_{Invalid\ Cue} - RT_{Valid\ Cue}$), which provided a general measure of attention for the cues and simplified the follow-up analyses. Because exposure duration was absent from the significant three-way interaction, CVIs were averaged over the exposure conditions. CVIs for the neutral cues were also subtracted from CVIs calculated for the other cue types to reveal the relative effects of valence and arousal.

A 2 × 2 repeated-measures ANCOVA was performed on the CVIs to examine the effects of valence (threatening vs. appetitive) and arousal (low vs. high) on attention for the cues. Consistent with the omnibus analysis, state and trait anxiety scores were included as covariates and were nonsignificant, Fs ≤ 2.84, ps ≥ .100. An effect of arousal was found, $F(1, 37) = 25.91$, $MSE = 363.15$, $p < .001$, $\eta_p^2 = .41$. CVIs were smaller for the high arousing cues (M = -10 ms, SE = 2.76) compared to the low arousing cues (M = 5 ms, SE = 2.86), suggesting that attention oriented more readily to pictures rated lower in arousal. The effect of valence was nonsignificant, $F < 1$, with comparable CVIs for the threatening (M = -4 ms, SE = 2.52) and appetitive cues (M = -2 ms, SE = 3.20). A Valence × Arousal interaction, however, was observed, $F(1, 37) = 17.65$, $MSE = 265.20$, $p < .001$, $\eta_p^2 = .32$, and is depicted in Figure 5.9.

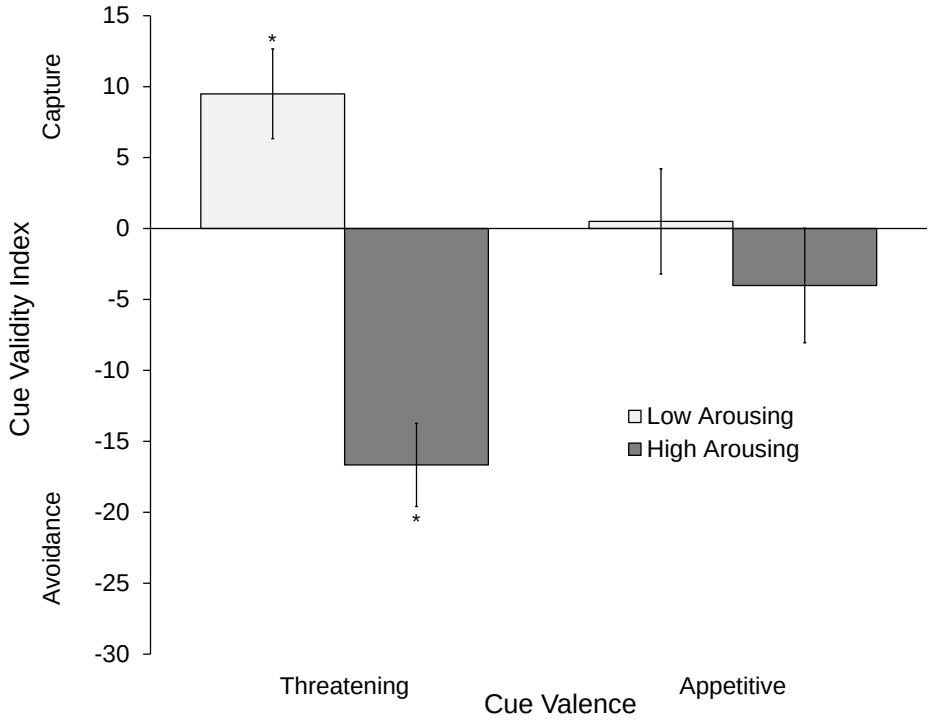

Figure 5.9. Cue validity indices as a function of valence and arousal, averaged over exposure conditions (Experiment 2.2). Zero = no difference from the neutral pictures. Error bars = standard errors. * denotes significant difference from zero, $p < .05$.

To decompose the significant Valence × Arousal interaction, the effect of arousal was tested separately for the threatening and appetitive cues. The simple effect of arousal was significant for the threatening pictures, $F(1, 37) = 66.66$, $p < .001$, $\eta_p^2 = .64$. CVIs were larger for the LAT cues (M = 9 ms, SE = 3.12) compared to the HAT cues (M = -17 ms, SE = 2.86). When the probes were cued by appetitive pictures, however, there was no significant difference in CVIs obtained by the LAA cues (M = 1 ms, SE = 3.73) and HAA cues (M = -4 ms, SE = 4.14), $F < 1$. As shown in Figure 5.9, CVIs obtained for the LAT cues were significantly greater than zero, reflecting enhanced attentional orienting relative to the neutral cues, $t(39) = 3.00$, $p = .005$, $d = 0.47$. In contrast, CVIs for the HAT pictures were significantly below zero,

consistent with attentional avoidance, $t(39) = 5.68$, $p < .001$, $d = 0.90$. CVIs obtained for the low and high arousing appetitive cues were not significantly different from zero, ts < 1.

Attentional bias indices. Indices of facilitated engagement and disengagement were calculated for each cue type to investigate how the distinct components of spatial attention were affected by the motivationally significant pictures. Given that the interaction between valence, arousal and validity did not vary across exposure conditions, indices of engagement and disengagement were averaged over exposure duration.

The engagement and disengagement indices obtained by the motivationally significant cue types are shown in Figure 5.10. Single sample *t*-tests were conducted to compare the indices against zero, reflecting no difference from the neutral cues. Engagement indices were significantly below zero for the LAT cues ($M = -5$, $SD = 10$), $t(39) = 3.32$, $p = .002$, $d = 0.53$, the HAT cues ($M = -24$, $SD = 17$), $t(39) = 8.97$, $p < .001$, $d = 1.42$, and the HAA cues ($M = -24$, $SD = 23$), $t(39) = 6.81$, $p < .001$, $d = 1.08$. These results suggest that participants' attention was more readily engaged by the neutral pictures and are consistent with attentional avoidance. Disengagement indices, on the other hand, were significantly greater than zero for the LAT cues ($M = 15$, $SD = 17$), $t(39) = 5.63$, $p < .001$, $d = 0.89$, the HAT cues ($M = 8$, $SD = 13$), $t(39) = 3.87$, $p < .001$, $d = 0.61$, and the HAA cues ($M = 20$, $SD = 27$), $t(39) = 4.87$, $p < .001$, $d = 0.77$, indicating that these pictures held attention longer compared to the neutral pictures. Engagement ($M = -3$, $SD = 11$) and disengagement indices ($M = 3$, $SD = 18$) for the LAA cues did not vary significantly from zero, ts ≤ 1.46, ps ≥ .153.

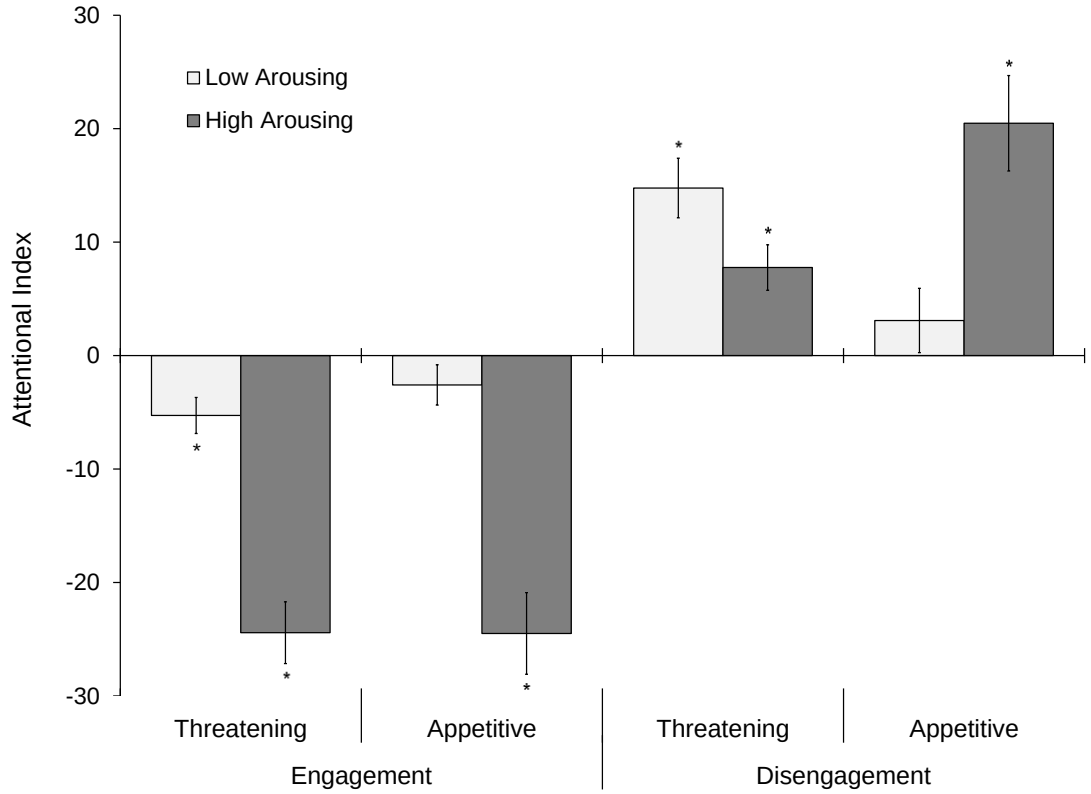

Figure 5.10. Attentional engagement and disengagement indices as a function of cue valence and arousal, averaged over exposure duration (Experiment 2.2). Zero = no difference from the neutral cues. Error bars = standard errors. * denotes significant difference from zero, $p < .05$.

Discussion

In Experiment 2.2 the ratio of valid to invalid trials was increased to 75:25. Because the cues indicated the correct location of the probe on 75% of trials, it was hypothesised that endogenous processes would enhance attentional orienting to the cues, facilitating faster responses on valid trials and slowing responses on invalid trials. Contrary to predictions, a main effect of cue validity was not observed. RTs were generally unaffected by whether the probes appeared in the same or opposite location as the preceding picture, suggesting that spatial attention was not attracted to the cues. Although the four-way interaction between valence, arousal, validity,

and exposure duration was nonsignificant, a significant three-way interaction emerged when RTs were averaged over exposure condition, indicating a combined effect of valence and arousal on spatial attention. After calculating CVIs as a general measure of attention for the cues, the individual and combined effects of valence and arousal were examined to investigate which stimulus dimensions affected attentional orienting.

In contrast to models assuming that spatial attention preferences emotional stimuli on the basis of threatening features or negative valence (Beck & Clark, 1997; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Öhman, 1996; Öhman & Mineka, 2001; Williams et al., 1988, 1997), CVIs were comparable for the threatening and appetitive pictures. According to the arousal hypothesis, if motivationally significant stimuli preferentially capture attention on the basis of arousal (Lang et al., 1997, 1998; Schimmack, 2005), larger CVIs should have been obtained by pictures rated as more arousing. Although stimulus arousal was found to have a significant effect on attention for the cues, the opposite pattern was observed. That is, larger CVIs were recorded for the low arousing pictures relative to the high arousing pictures. Contrary to the findings reported by Vogt et al. (2008), this result suggests that attention was oriented *away* from the high arousing cues at the time of probe onset. IoR from high arousing stimuli may reflect an emotional regulation mechanism that functions to regulate affective and physiological reactions by minimising the processing of provocative stimuli (Ellenbogen et al., 2002; Ellenbogen et al., 2006). This interpretation, however, conflicts with motivational significance theory (Lang et al., 1997, 1998), which predicts that spatial attention will orient more readily to high arousing stimuli that are relevant to survival and the reproductive needs of the species.

Although the effect of valence on the CVIs was nonsignificant, attention for the pictures was affected by a significant Arousal × Valence interaction. Replicating the results of Experiment 2.1, attention appeared to orient more readily to the less arousing, threatening pictures depicting interpersonal aggression compared to the more arousing pictures of blood injuries and mutilations. CVIs obtained by the HAT cues were not only significantly smaller than those calculated for the LAT cues, they were also less than zero. A negative CVI occurs when participants respond slower on valid trials compared to invalid trials and is considered to reflect IoR (Koster, Crombez et al., 2007; Waters et al., 2007). One explanation for these data is that when participants were exposed to the pictures of blood injuries and mutilations, their attention shifted to another spatial location as a means of inhibiting further stimulus processing, as predicted by the two-stage model (Williams et al., 1988, 1997). In contrast, the LAT cues appeared to attract attention, as indicated by a positive CVI that was significantly greater than zero. In the context of the motivational model of emotion (Lang et al., 1997, 1998), pictures of interpersonal aggression may have attracted enhanced attention due to moderate activation of the defensive motivational system. In comparison, more intense activation of the defensive system may trigger avoidance, as observed for the HAT pictures.

When appetitive pictures were presented before the probe, there was no difference in CVIs for the low and high arousing cue types. This suggests that attention for the appetitive pictures was unaffected by arousal value. In contrast to studies that have reported enhanced attentional orienting to appetitive stimuli (Brosch et al., 2008; Brosch et al., 2007; Maner, Gailliot, & DeWall, 2007; Maner, Gailliot, Rouby et al., 2007; Mogg et al., 1998; Nummenmaa et al., 2011; Pool et al., 2016; Sui & Liu, 2009), CVIs obtained by the LAA and HAA cues were not

significantly different from zero, suggesting that spatial attention did not preference appetitive pictures depicting infant rearing and heterosexual erotica relative to the neutral pictures. A different pattern of findings, however, was found when the distinct components of spatial attention were examined.

With the exception of the LAA pictures, the motivationally significant cues yielded engagement indices that were significantly *below* zero, indicating that attentional engagement favoured the neutral pictures. Disengagement indices, on the other hand, were significantly *greater* than zero for all cue types, except the LAA pictures. Aside from the pictures depicting infant rearing, the motivationally significant cues appeared to hold attention for longer compared to the neutral pictures. On the basis of these data, it appears that HAA stimuli did affect spatial attention by slowing attentional engagement and disengagement, whereas the LAA stimuli did not.

Conflicting interpretations of avoidance and delayed disengagement are difficult to reconcile, however, in terms of spatial attention. Considering that slower responses were observed on both valid and invalid trials employing LAT, HAT, and HAA cues, the negative engagement and positive disengagement indices obtained for these stimuli may have been influenced by interference effects that are unrelated to the orienting of spatial attention. That is, the motivationally significant pictures could have demanded greater processing resources, or slowed the speed of information processing, independently of spatial attention, but which delayed responses to the probe nonetheless.

The possibility that the attentional indices obtained in the current experiment were influenced by arousal-driven interference is supported by the Arousal × Exposure Duration interaction, with the high arousing pictures prompting slower

RTs in each exposure condition, irrespective of cue validity. This finding demonstrates that information processing is affected by stimulus arousal, even after controlling for individual differences in state and trait anxiety. Interestingly, the effect of arousal on RTs was most pronounced following 400 ms of cue exposure, and was comparatively weaker in the 100 ms and 1000 ms exposure conditions, suggesting that the influence of stimulus arousal on information processing builds during the first 400 ms post-stimulus onset and starts to decline by 1000 ms.

The effect of arousal converges with results reported by Schimmack (2005), who observed slower detection latencies for probes that appeared in the presence of high arousing pictures, regardless of valence. Consistent with studies that have employed the emotional Stroop task (Dresler et al., 2009), the notion of arousal-driven interference implies that participants were less capable of ignoring the affective content of the high arousing cues relative to the low arousing cues. Presumably, as cue arousal increased, the pictures consumed more processing resources that could not otherwise be utilised for detecting the probes. This interpretation proposes that stimuli interfere with task performance on the basis of their motivational significance, as indexed by arousal.

Although a general response slowing effect may explain why negative engagement and positive disengagement indices were obtained by the motivationally significant cues, this interpretation does not explain the CVIs observed for the LAT and HAT pictures. Recall that CVIs reflect the difference between valid and invalid trials for a given cue type. If non-spatial interference produced response slowing, it would presumably affect both valid and invalid trials to the same degree. The observation of faster RTs on valid trials employing LAT cues compared to invalid trials using the same stimuli demonstrates that pictures of interpersonal aggression

readily captured attention and supports the interpretation that these stimuli delayed disengagement. Thus, it seems that when spatial expectancies were violated by an invalid cue, the LAT pictures held attention for longer compared to the neutral pictures. The converse finding of slower RTs for valid trials relative to invalid trials when the probes were preceded by HAT cues indicates comparatively faster disengagement from the pictures of mutilations and blood injuries. Delayed disengagement from the LAT pictures contrasts with the findings reported by Vogt et al. (2008), who found that attention was slower to disengage from high arousing stimuli. These discordant results can be explained by the different types of pictures used to represent less arousing, threatening stimuli. Vogt et al. (2008) employed a heterogeneous set of pictures, which depicted pollution, poverty, and elderly people. Although negative in valence, such pictures are more likely to elicit feelings of sadness than threat. In contrast, the high arousing, negative stimuli used by Vogt et al. (2008) comprised of pictures that were more consistent with the LAT stimuli used in the current study, including pictures of human attacks and violence.

Another problem in interpreting the current findings in terms of the distinct components of spatial attention concerns the absence of exposure duration from the high-order interaction involving cue validity, valence, and arousal. Previous spatial cueing studies have demonstrated that attentional engagement, disengagement, and avoidance operate during distinct stages of information processing (Cisler et al., 2009; Cisler & Koster, 2010; Koster, Crombez, Verschuere, Van Damme et al., 2006; Koster, Crombez et al., 2007). Indeed, the phenomenological characteristics of these processes logically dictate that attention must engage a stimulus before disengaging and subsequently avoiding it (Cisler et al., 2009). Therefore, evidence of facilitated engagement was expected following brief exposure to the cues, while

delayed disengagement and avoidance were expected in the longer exposure conditions. Surprisingly, the interaction between cue type and validity did not vary with exposure duration, suggesting that spatial attention for the cues did not differ along the time-course of information processing.

Despite predictions that the cues would attract attention, as reflected by a positive cue validity effect, the main effect of cue validity was nonsignificant. This result is surprising given that a positive cue validity effect appears to be a robust finding in the existing literature (Briggs & Martin, 2008; Ellenbogen & Schwartzman, 2009; Koster, Crombez, Van Damme et al., 2004; Koster, Crombez, Verschuere, Van Damme et al., 2006; Koster, Crombez et al., 2007; Sagliano, Trojano et al., 2014; Vogt et al., 2008). One explanation for the discordant results is that prolonged exposure to the cues in the 1000 ms exposure condition may have produced an enduring effect on the allocation of spatial attention that influenced responses in the briefer exposure conditions, in which positive cueing effects were expected to occur. Supporting this explanation, IoR has been robustly observed at 1000 ms post-stimulus onset (Castel, Chasteen, Scialfa, & Pratt, 2003; Castel, Pratt, Chasteen, & Scialfa, 2005; Castel, Pratt, & Drummond, 2005; Samuel & Kat, 2003) and shown to be resistant to volitional attempts to attend to cued locations (Berlucchi, Chelazzi, & Tassinari, 2000). There is also evidence that IoR can operate over an extended time-course and affect responding on subsequent trials (Dodd & Pratt, 2007; Jongen & Smulders, 2007; Maylor & Hockey, 1987; Samuel & Kat, 2003; Tipper, Grison, & Kessler, 2003). In light of these findings, the absence of a positive cue validity effect in the current experiment may be attributable to IoR carrying-over from the 1000 ms exposure condition to the briefer exposure conditions.

As described by Posner and Cohen (1984), it is assumed that IoR is preceded by rapid engagement of the cued location. In light of this, the exposure durations employed in Experiments 2.1 and 2.2 may not have been brief enough to probe attention while it was directed toward the cues. That is, by 100 ms, attention may have already engaged the pictures and shifted away before the onset of the probe. Consistent with this explanation, Waters et al. (2007) suggest that the use of full-colour photographs may facilitate rapid processing of the pictures' content, thereby allowing quick shifts of attention away from the cued location. Attentional biases may therefore have occurred in Experiment 2.2, but terminated prior to 100 ms. In the subsequent experiment, the exposure duration of the cues was reduced to ≤ 100 ms to determine whether enhanced orienting may operate during very early stages of information processing.

Experiment 2.3

In Experiment 2.2, the absence of attentional biases toward the motivationally significant pictures could have been due to the length of cue exposure, which varied between 100 ms and 1000 ms. Earlier spatial cueing studies have demonstrated that the orienting of attention to affective stimuli occurs rapidly (≤ 120 ms; Junghöfer, Bradley, Elbert, & Lang, 2001; Koster, Crombez et al., 2007; Schupp, Junghöfer et al., 2004; Schupp, Markus, Weike, & Hamm, 2003; Smith, Cacioppo, Larsen, & Chartrand, 2003). When stimuli have been presented subliminally through the use of backward masking procedures, evidence of facilitated engagement has been observed in the dot-probe task (Carlson & Reinke, 2008). Consistent findings have also been reported in emotional Stroop studies that have employed subliminal exposure and backward masking procedures (Bradley, Mogg, Millar, & White, 1995; Edwards et al., 2010a, 2010b; MacLeod & Hagan, 1992; MacLeod & Rutherford, 1992; Mogg, Bradley, Williams, & Mathews, 1993; Mogg, Kentish, & Bradley, 1993). Putman, Hermans, and van Honk (2004) observed greater interference for naming the colour of schematic faces displaying an angry expression relative to neutral and happy faces. These effects, however, were only observed when stimuli were presented briefly (25 ms) and followed by a backward mask that prevented conscious processing. In light of these findings, facilitated attention to threatening or high arousing stimuli may be more reliably observed under conditions that restrict conscious processing.

The unexpected results in Experiment 2.2 could be due to IoR effects observed in the 1000 ms exposure condition carrying over to trials employing briefer cue durations, thereby masking enhanced attention for the motivationally significant pictures in the 100 ms and 400 ms exposure conditions. Employing a non-emotional

version of the SCT, Cheal and Chastain (2002) demonstrated that the range of SOAs between the cues and the probe can influence attentional orienting. IoR emerged later when the range of SOAs was short (i.e., 100-400 ms) compared to when a larger range of SOAs was employed (i.e., 100 -700 ms). In Experiments 2.1 and 2.2, the cues were exposed for between 100 and 1000 ms prior to the onset of the probe. In light of Cheal and Chastain's (2002) findings, the large variability in SOAs may have promoted early onset of IoR, thereby slowing RTs on valid trials.

In the current experiment, the exposure duration of the cues was reduced to ≤ 100 ms to examine whether spatial attention is preferentially allocated to motivationally significant pictures during very early stages of information processing. Restricting the length of cue exposure also ensured less variation in SOAs between the cues and probes, which has been shown to prolong attentional facilitation effects and delay the onset of IoR (Cheal & Chastain, 2002). A positive cue validity effect was therefore hypothesised, with faster responding on valid trials than invalid trials. Consistent with predictions of the previous experiments, the positive cue validity effect was expected to be augmented on the basis of cue type, as indicated by higher order interactions involving cue validity, valence, and arousal. Under the assumption that attention orients rapidly to threatening stimuli (Öhman, 1996; Öhman & Mineka, 2001), a combined effect of cue validity and valence was hypothesised. In contrast to the neutral and appetitive pictures, threatening pictures were expected to facilitate faster responses on valid trials, consistent with facilitated engagement of threat, while slowing responses on invalid trials, indicative of delayed disengagement. In contrast to the threat-superiority hypothesis, attentional orienting may preference motivationally significant stimuli irrespective of valence (Bradley & Lang, 2007; Lang et al., 1997, 1998). According to this competing view, faster

responses on valid trials were expected following the presentation of high arousing pictures compared to low arousing pictures, consistent with facilitated engagement of motivationally significant stimuli. On invalid trials, however, the high arousing pictures were expected to slow responses compared to the low arousing cues, demonstrating delays to attentional disengagement.

With respect to time-course, the extent to which attention is allocated to affectively valenced pictures during very early stages of processing (≤ 100 ms) has rarely been examined in studies employing the SCT. Assuming, however, that attentional orienting to threatening or motivationally significant stimuli occurs rapidly after stimulus onset (Bradley, 2009; Öhman, 1996; Öhman & Mineka, 2001), and operates below the threshold of conscious awareness (Carlson & Reinke, 2008), facilitated engagement effects were expected to be observed in the 24 ms exposure condition. Delayed disengagement, however, presumably requires some degree of conscious processing (Cisler & Koster, 2010), and was therefore anticipated to occur in the 59 ms and 100 ms exposure conditions.

Method

Participants

Forty-six participants were recruited for Experiment 2.3. One participant's data were excluded because they did not consider members of the opposite gender to be sexually appealing. The remaining sample of 45 participants included 35 females (77.78%). Participants were aged between 18 and 56 years (M = 21.82, SD = 6.95). Scores on the STAI-S varied between 20 and 49 (M = 32.84, SD = 7.61), while STAI-T scores ranged from 25 to 68 (M = 39.38, SD = 10.28).

Materials & Procedure

The SCT adopted the same parameters employed in Experiment 2.1, with the exception of the exposure duration of the cues. To capture very early stages of attentional processing, the cues were presented for 24 ms, 59 ms, and 100 ms before the onset of the probes. Because exogenous processes are assume to underlie attentional engagement during early, automatic stages of stimulus processing (Carlson & Reinke, 2008; Cisler et al., 2009; Cisler & Koster, 2010; Koster, Crombez et al., 2007), an equal proportion of valid to invalid trials was adopted, enhancing the task's sensitivity for detecting facilitated engagement effects. All materials and procedures were otherwise consistent with the previous experiments.

Results

Data Preparation

RTs corresponding to incorrect responses were removed (1.23% of test trials). No univariate outliers were observed with respect to the percentage of errors made on the task. One participant, however, was found to have made an outlying number of anticipatory responses (< 150 ms), equating to 5.21% of the test trials. As the same participant responded to 25% of the catch trials, the case was removed. For the remaining cases, correct responses occurring outside of 150-750 ms were excluded (0.47% of test trials). Additionally, RTs that fell outside of ± 2 *SD*s from a participant's mean RT for each experimental condition were also removed (3.64% of test trials). Analyses were performed on 94.73% of the test trial data obtained from the 44 remaining participants.

Statistical Assumptions

Employing the same procedures used in Experiment 2.1, data screening revealed an absence of univariate outliers in the final data set. Although the

distribution of RT data was positively skewed for most of the experimental conditions, the pattern of results remained unchanged following a logarithmic transformation. To preserve interpretability, results for the untransformed RTs are reported. Mauchley's test demonstrated that the assumption of sphericity was met.

Catch Trials

On average, participants responded to 6.68% of the catch trials (*SD* = 7.46), confirming that they typically responded to the location of the probes, not the cues. Catch trial responses did not vary significantly as a function of cue type, $F(4, 172) = 1.41$, $MSE = 188.59$, $p = .233$, $\eta_p^2 = .03$.

Accuracy Data

Accuracy on the test trials was high. The proportion of correct responses ranged from 96% to 100% (*M* = 98.83%, *SD* = 0.01), precluding analysis of the accuracy data.

Reaction Time Data

Overall effects. Mean RTs recorded for the different cue types are reported in Table 5.5 for each exposure condition. These data were analysed using a 2 × 2 × 2 × 3 repeated-measures ANCOVA, with valence (threatening vs. appetitive), arousal (low vs. high), validity (valid vs. invalid), and exposure duration (24 ms vs. 59 ms vs. and 100 ms) as factors. STAI-S and STAI-T scores were included as covariates and were nonsignificant, *F*s < 1. Neither state nor trait anxiety interacted with cue valence or arousal, *F*s < 1. After controlling for state and trait anxiety, a reverse cue validity effect was revealed, $F(1, 41) = 27.89$, $MSE = 1982.84$, $p < .001$, $\eta_p^2 = .41$, with slower responding on valid trials (*M* = 301 ms, *SE* = 5.76) than invalid trials (*M* = 287 ms, *SE* = 6.32). A main effect of exposure duration was also found, $F(2, 82) = 18.74$, $MSE = 397.71$, $p < .001$, $\eta_p^2 = .31$. Responses were faster in the 24 ms

exposure condition (*M* = 289 ms, *SE* = 5.96) relative to the 59 ms exposure condition (*M* = 296 ms, *SE* = 5.82), $F(1, 41) = 24.45$, $MSE = 42.45$, $p < .001$, $\eta_p^2 = .37$. RTs observed in the 59 ms and 100 ms (*M* = 298 ms, *SE* = 6.08) exposure conditions, however, were not significantly different, $F(1, 41) = 1.61$, $MSE = 47.84$, $p = .212$, $\eta_p^2 = .04$. A main effect of valence also emerged from the omnibus analysis, $F(1, 41) = 7.27$, $MSE = 299.37$, $p = .010$, $\eta_p^2 = .15$, with slower responding to probes preceded by threatening cues (*M* = 295 ms, *SE* = 5.82) compared to appetitive cues (*M* = 293 ms, *SE* = 6.00). The main effect of arousal was nonsignificant, $F(1, 41) = 2.79$, $MSE = 232.85$, $p = .102$, $\eta_p^2 = .06$.

Table 5.5

Mean Response Times (ms), Standard Deviations (SD), and Cue Validity Indices (CVI) as a Function of Cue Type, Validity and Exposure Duration in Experiment 2.3.

		Exposure Duration								
		24 ms			59 ms			100 ms		
Cue Type	Cue Validity	*M*	*SD*	CVI	*M*	*SD*	CVI	*M*	*SD*	CVI
Low Arousing Threatening	Valid	288	38	-2	303	44	-14	301	38	-8
	Invalid	286	41		289	42		293	48	
Low Arousing Appetitive	Valid	292	43	-6	304	41	-17	310	43	-30
	Invalid	286	48		287	41		280	48	
High Arousing Threatening	Valid	295	38	-9	310	41	-24	319	42	-31
	Invalid	287	43		286	45		288	47	
High Arousing Appetitive	Valid	289	41	-1	301	44	-16	303	43	-16
	Invalid	288	45		285	43		287	50	
Neutral	Valid	288	35	-2	296	37	-11	300	37	-15
	Invalid	287	42		286	43		285	43	

The omnibus ANCOVA also revealed two-way interactions between valence and arousal, $F(1, 41) = 7.36$, $MSE = 33.07$, $p = .010$, $\eta_p^2 = .15$, and validity and exposure duration, $F(2, 82) = 12.35$, $MSE = 599.39$, $p < .001$, $\eta_p^2 = .23$, in addition to a three-way interaction between valence, arousal and validity, $F(1, 41) = 19.75$, $MSE = 343.44$, $p < .010$, $\eta_p^2 = .33$. These lower-order interactions were qualified by a significant four-way interaction between valence, arousal, validity, and exposure duration, $F(2, 82) = 3.28$, $MSE = 367.14$, $p = .043$, $\eta_p^2 = .07$. All other interactions were nonsignificant, Fs ≤ 2.77, ps $\geq .104$.

To interpret the significant four-way interaction, separate 2 × 2 × 2 ANCOVAs were conducted at each level of exposure duration, with valence, arousal, and validity as within-subjects factors. Consistent with omnibus analysis, state and trait anxiety scores were included as covariates and were nonsignificant, Fs < 1.

24 ms. The effect of cue validity was nonsignificant in the 24 ms exposure condition, as were the effects of valence and arousal, Fs ≤ 2.50, ps $\geq .121$. The two- and three-way interactions were also nonsignificant, Fs ≤ 3.32, ps $\geq .076$. The absence of a significant interaction involving cue validity suggests that no differential cueing effects occurred in the 24 ms exposure condition.

59 ms. A reverse cue validity effect emerged when the cues were exposed for 59 ms. Slower responding was observed on valid trials ($M = 305$ ms, $SE = 6.14$) than invalid trials ($M = 287$ ms, $SE = 6.13$), $F(1, 41) = 21.42$, $MSE = 1328.56$, $p < .001$, $\eta_p^2 = .34$. RTs were not significantly affected by valence or arousal, Fs ≤ 2.29, ps $\geq .138$. None of the interactions were significant, Fs ≤ 1.64, ps $\geq .207$, indicating that the reverse cue validity effect was unaffected by the valence or arousal of the cues.

100 ms. A reverse cue validity effect was found in the 100 ms exposure condition, with slower RTs on valid trials (M = 308 ms, SE = 5.90) than invalid trials (M = 287 ms, SE = 6.81), $F(1, 41) = 31.57$, $MSE = 1272.96$, $p < .001$, $\eta_p^2 = .44$. A significant effect of valence was also observed, $F(1,41) = 8.27$, $MSE = 292.92$, $p = .006$, $\eta_p^2 = .17$. Responses to the probe were slower following the presentation of threatening pictures (M = 300 ms, SE = 6.01) compared to appetitive pictures (M = 295 ms, SE = 6.28). The effect of arousal was nonsignificant, $F(1,41) = 2.09$, $MSE = 380.38$, $p = .156$, $\eta_p^2 = .05$. Although none of the two-way interactions were significant, Fs ≤ 1.04, ps $\geq .313$, a significant three-way interaction between valence, arousal, and validity emerged, $F(1,41) = 18.46$, $MSE = 415.49$, $p < .001$, $\eta_p^2 = .31$, indicating a combined effect of valence and arousal on the allocation of spatial attention.

Cue validity indices. Using RTs obtained in the 100 ms exposure condition, CVIs ($RT_{\text{Invalid Cue}} - RT_{\text{Valid Cue}}$) were calculated to yield a general measure of attention for the cues. CVIs for the neutral cues were subtracted from CVIs calculated for the other cue types, thereby providing a measure of attentional orienting to the motivationally significant cue types relative to the neutral cues. These values were subjected to a 2 × 2 ANCOVA to determine the effects of valence and arousal on attention, after controlling for state and trait anxiety. Although the main effects of valence and arousal were nonsignificant, Fs ≤ 1.04, ps $\geq .313$, a significant Valence × Arousal interaction was observed, $F(1,41) = 18.46$, $MSE = 830.98$, $p < .001$, $\eta_p^2 = .31$. As can be seen in Figure 5.11, cue arousal had differential effects on attention for the threatening and appetitive stimuli. When the probes were cued by threatening pictures, CVIs were larger for low arousing pictures (M = 7, SE = 4.37) compared to high arousing pictures (M = -16, SE = 4.81), F(1,

41) = 17.77, *MSE* = 645.78, $p < .001$, $\eta_p^2 = .30$. Conversely, when the cues were positively valenced, CVIs were larger following the presentation of high arousing pictures (*M* = -1, *SE* = 4.81) relative to low arousing pictures (*M* = -16, *SE* = 4.11), $F(1, 41) = 5.05$, *MSE* = 917.08, $p = .030$, $\eta_p^2 = .11$. Notably, CVIs obtained by the HAT and LAA cues were significantly below zero, with $t(43) = 3.24$, $p = .002$, $d = .49$, and $t(43) = 3.86$, $p < .001$, $d = .58$, respectively. These findings suggest that attention oriented more readily to the neutral pictures than the HAT and LAA pictures at 100 ms post-stimulus onset. CVIs for the HAA and LAT cues did not vary significantly from zero, $ts \leq 1.55$, $ps \geq .129$.

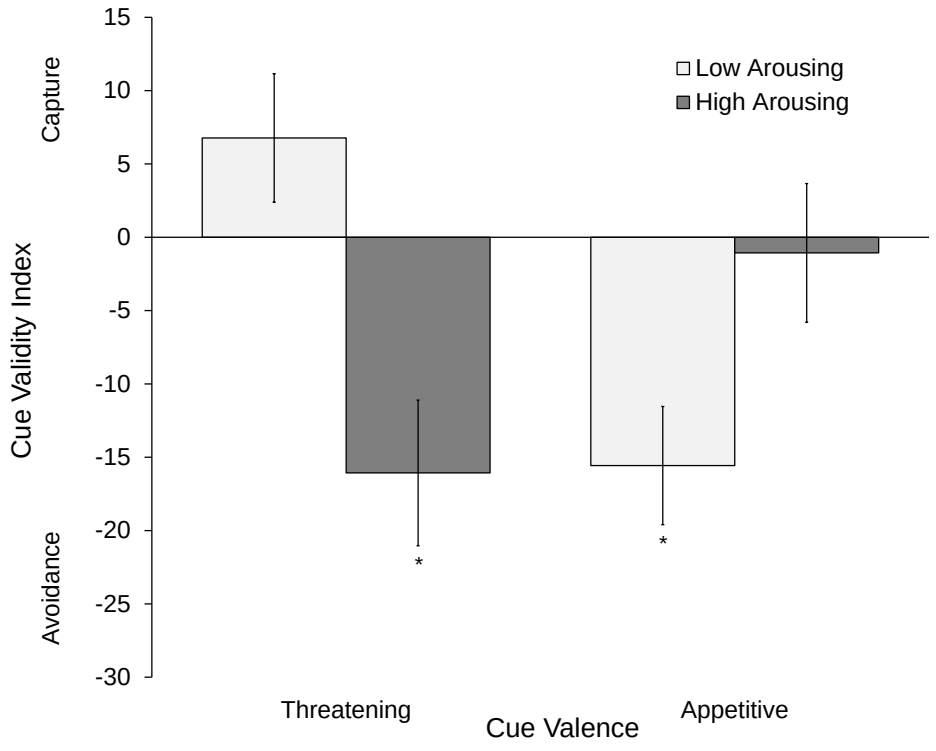

Figure 5.11. Cue validity indices in the 100 ms exposure condition as a function of cue valence and arousal (Experiment 2.3). Zero = no difference from the neutral cues. Error bars = standard errors. * denotes significant difference from zero, $p < .05$.

Attentional bias indices. Indices of attentional engagement and disengagement were calculated to examine how the specific components of attention were affected by the motivationally significant cues in the 100 ms exposure condition. The mean engagement and disengagement indices obtained by the different cue types are plotted in Figure 5.12. Engagement indices were significantly below zero for the HAT cues (M = -18, SD = 23), $t(43) = 5.36$, $p < .001$, $d = 0.81$, and the LAA cues (M = -10, SD = 24), $t(43) = 2.63$, $p = .012$, $d = 0.40$, reflective of attentional avoidance. In contrast, engagement indices for the HAA (M = -3, SD = 22) and LAT cues (M = -1, SD = 19) did not vary significantly from zero, ts < 1. Delayed disengagement was observed for the LAT cues, as indicated by a disengagement index that was significantly greater than zero (M = 8, SD = 21), $t(43) = 2.40$, $p = .021$, $d = 0.36$. Disengagement indices for the other cue types did not vary significantly from zero, ts ≤ 1.84, ps ≥ .073.

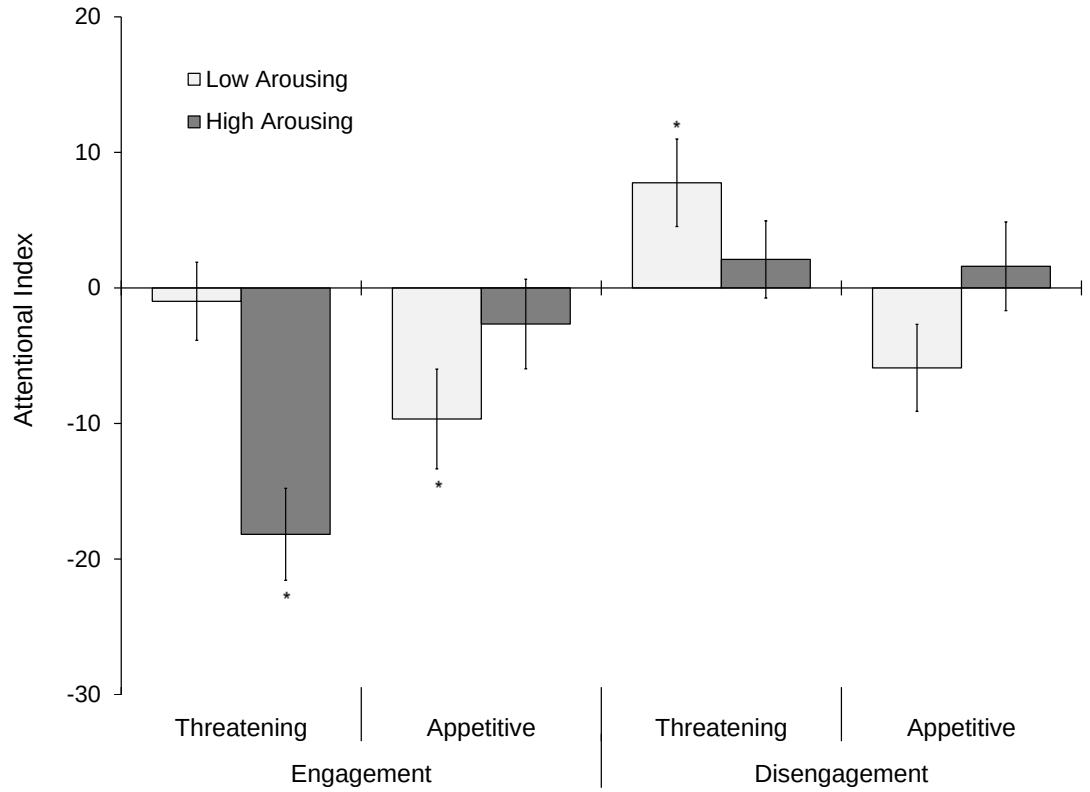

Figure 5.12. Attentional engagement and disengagement indices as a function of cue valence and arousal in the 100 ms exposure condition (Experiment 2.3). Zero = no difference from the neutral cues. Error bars = standard errors. * denotes significant difference from zero, $p < .05$.

Discussion

By reducing the exposure duration of the pictures to ≤ 100 ms, the cues were hypothesised to facilitate faster responding on valid trials and slower responding on invalid trials, consistent with a positive cue validity effect. Despite the briefer exposure conditions, however, a *reverse* cue validity effect was observed, with slower RTs on valid trials compared to invalid trials. In agreement with Experiment 2.1, these data suggest that participants' attention was generally oriented away from the pictures at the time of probe onset. Given the brief exposure duration of the

pictures (≤ 100 ms), overt shifts of attention are unlikely to have occurred (Remington, 1980). Rather, the current results can be confidently attributed to presaccadic processes. Previous studies employing the non-emotional variants of the SCT have demonstrated that IoR typically emerges ~ 300 ms post-stimulus onset and is facilitated by oculomotor movements (Kingstone & Pratt, 1999; Klein, 2000; Posner & Cohen, 1984; Posner, Rafal, Choate, & Vaughan, 1985; Samuel & Kat, 2003; Taylor & Klein, 1998). IoR is therefore an unlikely explanation as to why participants' responses were generally slower for validly cued probes following only brief exposure to the cues.

The main effect of cue valence revealed that overall response latencies were slowed following the presentation of threatening pictures compared to appetitive pictures. In contrast to the previous experiments, the effect of arousal was nonsignificant. Considered together, these findings suggest that the effects of valence operate during earlier stages of processing, perhaps reflecting rapid activation of the defensive motivational system (Lang et al., 1998; LeDoux, 1996), whereas the effects of arousal may operate along a slower time-course. As the effect of valence on RTs was independent of cue validity, this finding cannot be attributed to spatial attention and is better explained in terms of non-spatial interference or a cognitive form of the freezing response. In agreement with this interpretation, Estes and Verges (2008) demonstrated that when stimulus valence is irrelevant to task requirements, as was the case in the current experiment, threatening stimuli can suppress responding and inflate RTs, similar to the freezing response that many animals exhibit when under threat. Moreover, given that individual differences in state and trait anxiety were controlled for, threat-induced response slowing appears to occur over and above the effects of anxiety.

A four-way interaction indicated that the reverse cue validity effect varied as a function of valence, arousal, and exposure duration. Follow-up analyses were conducted at each level of exposure and revealed a combined effect of valence and arousal on attentional orienting at 100 ms post-stimulus onset. Using CVIs as a general measure of attention for the pictures, a disordinal interaction between valence and arousal emerged, with arousal having opposing effects on spatial orienting to the threatening and appetitive pictures. Increased stimulus arousal appeared to diminish attention for the threatening pictures, as demonstrated by smaller CVIs for pictures of mutilations and blood injuries compared to pictures depicting interpersonal aggression. Conversely, attention for the appetitive pictures was enhanced by stimulus arousal, with larger CVIs for the erotic pictures compared to pictures of infant rearing. CVIs were significantly below zero for the HAT and LAA pictures, indicating that they captured attention less readily than the neutral pictures.

In agreement with studies that have observed delayed disengagement from moderately threatening pictures in non-anxious participants (Koster, Crombez et al., 2007; Sagliano, Trojano et al., 2014), examination of the attentional bias indices revealed a positive disengagement index for the LAT cues, indicating that participants' attention was slower to disengage from pictures depicting interpersonal aggression compared to the neutral pictures. Although engagement indices were expected to be potentiated for the motivationally significant pictures, demonstrating facilitated attentional engagement, this hypothesis was not supported. None of the cue types obtained a positive engagement index, indicating that attentional engagement generally favoured the neutral pictures. Furthermore, in contrast to studies that have reported enhanced engagement of highly threatening pictures in

non-anxious participants (Koster, Crombez et al., 2007), engagement indices obtained by the HAT pictures were significantly lower than those obtained by the neutral pictures. Interestingly, lower engagement indices were also recorded for the LAA pictures. These findings are consistent with the pattern of the disordinal interaction observed using the CVIs and suggest that participants' attention was directed away from the pictures of blood injuries and infant rearing by the time the probe appeared.

Since the cues were exposed for ≤ 100 ms, thereby probing very early stages of processing, interpreting the negative engagement indices obtained by the HAT and LAA pictures in terms of avoidance is problematic. Attentional avoidance is considered to be a strategically-mediated, endogenous process (Cisler et al., 2009; Cisler & Koster, 2010; Koster, Crombez, Verschuere, Van Damme et al., 2006; Mogg et al., 2004) and is therefore unlikely to have occurred under the brief exposure conditions employed in the current experiment. The negative engagement indices cannot be attributed to differential interference either. If the HAT and LAA pictures produced non-spatial interference, response slowing should have also been observed on invalid trials employing the same pictures. Slowed RTs for the HAT and LAA cues were limited, however, to valid trials, indicating that the effects were dependent on the probe's spatial proximity to the preceding picture.

Although unexpected, the disordinal interaction between valence and arousal observed in the current experiment is consistent with studies that have examined evaluative processing of affective pictures (Purkis et al., 2009; Robinson et al., 2004). When participants are instructed to rate pictures in terms of valence, Purkis et al. (2009) demonstrated that HAT and LAA stimuli are categorised faster as pleasant and negative, respectively, compared to HAA and LAT stimuli. Even when

evaluations of stimulus valence and arousal are irrelevant to task demands, a processing advantage has been observed for low arousing positive and high arousing negative pictures (Eder & Rothermund, 2010). These findings are also supported by neuropsychological studies that have found disordinal interactions between valence and arousal on early ERP components, with potentiated P2 and P3 amplitudes following the presentation of HAT and LAA pictures (Feng et al., 2012). Complementary research has also shown that appraisal of affective stimuli occurs rapidly (see Brosch, Pourtois, & Sander, 2010 for a review), with picture rating studies reporting valence- and arousal-dependent evaluative judgments of pictures following 25 ms of exposure, coupled with cortical and physiological reactions indicative of emotional processing (Codispoti, Mazzetti, & Bradley, 2009). Collectively, these findings demonstrate that the affective content of HAT and LAA stimuli is processed rapidly during very early stages of information processing. The negative engagement indices obtained by the HAT and LAA cues in the current experiment could therefore reflect that these pictures were processed rapidly ($\leq$ 100 ms), thus allowing attention to covertly shift toward another spatial location prior to the onset of the probes.

The failure to observe evidence of enhanced attention for the motivationally significant cues may also be due to the spatiotemporal arrangement of the cues relative to the probes. Because the cues and probes appeared within close temporal proximity and spatially overlapped on the valid trials, it is possible that the affective pictures disrupted detection of the probes. When exposed to rapid serial presentations of visual stimuli, participants typically fail to detect the presence of a non-affective target when it is preceded by a negatively valenced picture (Kennedy & Most, 2015; Most, Chun, Widders, & Zald, 2005) or an aversively conditioned

stimulus (Smith, Most, Newsome, & Zald, 2006). This phenomenon, referred to as *emotion induced blindness*, is not limited to negatively valenced stimuli, with several studies reporting impaired detection of targets occurring within close temporal proximity to high arousing appetitive stimuli, including opposite-sex erotica (Most, Smith, Cooter, Levy, & Zald, 2007), sex-related words (Arnell, Killman, & Fijavz, 2007), and pictures of food following a period of fasting (Piech, Pastorino, & Zald, 2010). In the current experiment, emotion induced blindness may explain why the motivationally significant pictures slowed responding to the probes on valid trials. Assuming that emotion induced blindness reflects enhanced attentional capture, the possibility that the motivationally significant stimuli preferentially engaged attention cannot be ruled out.

Chapter Summary

The findings from Study 2 indicate that a number of processes involved in visual attention are influenced by motivationally significant stimuli during the first 1000 ms of exposure. A main effect of valence in Experiment 2.3 revealed that responses were slowed following the presentation of threatening pictures during early stages of processing (≤ 100 ms). At later stages (≥ 100 ms), delayed responding was observed for the high arousing pictures, irrespective of valence (Experiments 2.1 & 2.2). These non-spatial slowing effects may reflect enhanced processing of the threatening and high arousing pictures, thereby leaving fewer resources for attending and responding to the probes. As these effects were independent of cue validity, they most likely reflect the effect of valence and arousal on non-spatial components of attention, such as processing speed and capacity. Because the cues and probes were separated by a brief inter-stimulus interval (12 ms), it is likely that they competed for the same processing resources (Isreal et al., 1980; Wickens et al., 1983). If the

threatening and high arousing cues attracted more resources, less capacity would have been available for processing the probes, thereby slowing response latencies. Supporting this explanation, electroencephalographic research has demonstrated that threatening and emotionally arousing pictures place greater demands on the visual cortex compared to affectively neutral pictures, resulting in reduced efficiency on concurrent tasks that are contingent on visual attention (Müller, Andersen, & Keil, 2008; Schönwald & Müller, 2014; Schupp, Markus, Weike, & Hamm, 2003; Vuilleumier, 2005). Considered together, the current results suggest that non-spatial interference operates as a function of valence during early stages of processing and arousal at later stages.

With respect to the orienting of spatial attention, the data revealed a reverse cue validity effect, with slower responding on valid trials compared to invalid trials. Even when the cues accurately indicated the location of the probe on 75% of trials (Experiment 2.2), and the exposure duration of the cues was reduced to ≤ 100 ms (Experiment 2.3), the valid cues failed to facilitate faster RTs. Previously interpreted as IoR, a negative cue validity effect suggests that participants' attention was generally directed away from the cues at the time of probe onset.

Early stages of processing were characterised by a complex interaction between stimulus valence and arousal (Experiment 2.3). Compared to the other cue types, spatial attention appeared to shift away from HAT and LAA pictures more readily and was inhibited from returning to their location, thereby delaying responses on valid trials while facilitating responses on invalid trials. IoR is assumed to occur only after attention has reflexively oriented toward a stimulus (Klein, 2000; Posner & Cohen, 1984). The findings from Experiment 2.3 were therefore interpreted in terms of rapid stimulus engagement, which resulted in early onset of IoR.

During later stages of processing, results indicated that IoR was enhanced for the high arousing stimuli (Experiment 2.1). Although IoR of neutral stimuli is regarded as an adaptive process that facilitates foraging and scanning of the environment (Klein & MacInnes, 1999), an attentional system that is unable to readily return to spatial locations occupied by threatening or appetitive stimuli is likely to jeopardise survival. Contrary to the current findings, several studies have demonstrated that IoR can be disrupted or attenuated by threatening and biologically-prepared stimuli (Fox et al., 2002; Theeuwes & Van der Stigchel, 2006; Yiend & Mathews, 2001). At later stages of processing, strategic avoidance appears to have directed attention away from HAT stimuli. In contrast to previous research (Amir, Elias, Klumpp, & Przeworski, 2003; Cisler & Olatunji, 2010; Fox et al., 2001; Fox et al., 2002; Georgiou et al., 2005; Koster, Crombez, Verschuere, Van Damme et al., 2006; Van Damme et al., 2006; Yiend & Mathews, 2001), individual differences in state and trait anxiety were not associated with RTs for the motivationally significant pictures in any of the experiments.

Despite predictions that the motivationally significant pictures would facilitate attentional engagement, the results from Experiments 2.1 and 2.2 revealed negative engagement indices for the high arousing cue types across all exposure conditions. Although these results are consistent with attentional avoidance, the same cues obtained positive disengagement indices within the 400 ms exposure condition in Experiment 2.2 and across all exposure conditions in Experiment 2.1, suggesting that attention was slower to shift *away* from the high arousing pictures. There was also evidence that attention was slower to disengage from the LAT pictures compared to the HAT pictures, and from HAA pictures compared to the LAA pictures (Experiment 2.2).

Concurrent observations of avoidance and delayed disengagement reflect that the high arousing pictures slowed responses on both valid and invalid trials relative to the neutral pictures. These results are difficult to reconcile in terms of spatial attention and indicate that the results may have been influenced by non-spatial interference, such as emotion-induced blindness (Arnell et al., 2007; Most et al., 2007), or a cognitive form of the freezing response (Fox et al., 2001; Sagliano, Cappuccio et al., 2014). Therefore, an alternative explanation for the reverse cue validity effect concerns the spatial arrangement of the cues relative to the probes. Specifically, the spatial overlap between the pictures and probes on valid trials may have produced a forward masking effect or persistent afterimage that interfered with detection of the probes. As proposed by Desimone and Duncan (1995), when visual stimuli appear within close spatiotemporal proximity, their neural representations compete for perceptual processing in the visual cortex. Supporting the notion of perceptual competition, neurocognitive studies have demonstrated that neurons in the visual cortex which respond to the presentation of a single stimulus are less reactive when a second stimulus is shown simultaneously within the same spatial vicinity (Chelazzi, Miller, Duncan, & Desimone, 2001). In contrast to valid trials, perceptual competition is less likely to have occurred when the cues and probes were spatially distinct on invalid trials. Although this interpretation may explain observations of a negative cue validity effect, it does not account for differential responding to the cue types, including the consistent finding of slowed RTs to validly cued probes that were preceded by high arousing pictures compared to low arousing pictures.

When conditions promote competition between affective and neutral stimuli, perception is assumed to be biased in favour of emotionally salient material (Vuilleumier, 2005). Consequently, perceptual enhancement of affective stimuli may

come at the expense of task-relevant information, if they that appear within close temporal and spatial proximity to each other (Bocanegra & Zeelenberg, 2009; Wang, Kennedy, & Most, 2012). For example, affective material has been shown to potentiate the attentional blink (Arnell et al., 2007; Most et al., 2005; Most et al., 2007), interfere with solving math problems (Schimmack, 2005), and delay colour naming (Algom et al., 2004; Pratto & John, 1991). These findings suggest that motivationally significant stimuli may bias perceptual competition, thereby consuming processing resources needed to detect task-focal stimuli appearing in the same location. Considered in the context of the current findings, arousal-biased competition may explain why responses were especially delayed for validly cued probes preceded by the high arousing pictures.

In addition to the spatiotemporal arrangement of the cues and the probes, another methodological factor that may have promoted the reverse cue validity effect concerns the nature of the task. IoR has been shown to be sensitive to task demands and is most reliably observed when participants are required to simply detect a probe or indicate its location (Klein, 2000; Lupiáñez, Milán, Tornay, Madrid, & Tudela, 1997). The observation of a reverse cue validity effect in the current experiments may therefore be partially attributable to the minimal demands a probe localisation task places on attentional resources, allowing attention to readily shift away from the cued location. That is, a localisation task may have lacked sufficient sensitivity for examining the allocation of spatial attention to motivationally significant pictures. In contrast a perceptually demanding task, such as discriminating between two perceptually distinct probes, is likely to elicit more enhanced attention to the cued location (Weierich, Treat, & Hollingworth, 2008).

CHAPTER VI

STUDY 3

The results of Study 2 were surprising given that inhibition of attention to motivationally significant stimuli is counterintuitive to evolutionary accounts of attentional bias (Bradley, 2009; Öhman, 1996; Öhman & Mineka, 2001). IoR could compromise survival and reproduction if attention were unable to return readily to potential threats or appetitive opportunities. In accordance with biased competition theory (Desimone & Duncan, 1995), observations of a reverse cue validity effect may be partially attributable to the spatiotemporal configuration of the cue and probe stimuli. That is, because the probes spatially overlapped with the cues on valid trials, in addition to appearing within close temporal proximity, it is possible they utilised the same processing resources, thereby disrupting perception of the probes and slowing responses. In contrast, the spatial arrangement on invalid trials is less likely to have interfered with detection of the probes, which appeared in the opposing spatial location.

McAuliffe and Pratt (2005) systematically examined the effect of spatiotemporal configuration on observations of attentional orienting using a non-emotional cueing task. Under brief cue exposure conditions (50 ms and 100 ms), faster responding was observed for cued relative to non-cued probes, but only when the probes were spatially distinct from the cues. In contrast, when the probes were presented in the same location as the preceding cues, facilitation effects were absent. Employing very brief cue durations (5-16 ms) and an SOA of 200 ms, Tassinari and Berlucci (1993) found that responses were delayed for probes preceded by a valid cue compared to probes appearing in the opposite periphery. In their study, the cues and probes were produced using light-emitting diodes (LEDs) and appeared in the

exact same location, resulting in complete spatial overlap. As proposed by McAuliffe and Pratt (2005), overlapping spatial arrangements may result in perceptual confusion between the cue and probe stimuli, thereby delaying detection of the probes on valid trials and slowing responses.

In a separate line of research, studies employing rapid serial presentation of pictures have demonstrated that emotionally-salient stimuli can impair detection of a target stimulus that appears within close spatiotemporal proximity (i.e., ≤ 100 ms; Kennedy & Most, 2015; Most et al., 2005; Most et al., 2007). Findings of emotion-induced blindness have been interpreted as reflecting competition for neural representation in the visual cortex, with prioritisation of emotional stimuli suppressing representations of neutral targets (Most & Wang, 2011; Wang et al., 2012). This explanation was supported by Müller et al. (2008), who had participants complete a difficult target detection task while task-irrelevant pictures were presented in the background. Target detection rates were lower when background pictures contained emotionally arousing content, which corresponded with reduced amplitude of visual evoked potentials. These findings demonstrate that processing resources in the visual cortex are reduced as a function of the emotional salience of spatially overlapping, but task-irrelevant, stimuli. Considered in the context of the SCT, the affective qualities of a stimulus are likely to interact with its spatiotemporal relationship to non-affective probes in such a way as to either facilitate or delay responding, which may mask more subtle spatial orienting effects, such as facilitated engagement. Therefore, in the current study, the location of the probes was adjusted to minimise spatial competition with the cues.

Another important methodological consideration concerns the nature of the task and how participants respond to the probe. Research employing non-emotional

versions of the spatial cueing paradigm has demonstrated that task requirements determine the time needed for attention to shift away and inhibit a cued location (Cheal & Chastain, 2002; Lupiáñez et al., 1997; Lupiáñez & Milliken, 1999; Lupiáñez, Milliken, Solano, Weaver, & Tipper, 2001). In these studies, IoR has been shown to operate earlier when participants are required to simply detect a probe or indicate its location, compared to probe classification tasks that require participants to discriminate between two visually distinct probes (e.g., X and O). Lupiáñez and Milliken (1999) observed IoR at a cue-probe SOA of 400 ms when participants completed a probe detection task. In contrast, when a probe classification task was employed, facilitated cueing effects were observed at 400 ms, and IoR did not occur until the SOA was extended to 700-1000 ms. Even at long SOAs (i.e., 500-1000 ms), some studies employing probe classification tasks have failed to observe IoR (Lupiáñez, Ruz, Funes, & Milliken, 2007; Terry et al., 1994), whereas others have reported facilitated cueing effects (Van der Lubbe, Vogel, & Postma, 2005).

The delayed onset or absence of IoR in classification tasks has been explained in terms of increased demands on perceptual processes, which are needed to discriminate between the probes (Lupiáñez & Milliken, 1999; Lupiáñez et al., 2001). Consistent with this interpretation, Lupiáñez et al. (2001) demonstrated that the onset of IoR during probe classification tasks is especially delayed when participants are required to discern between perceptually similar probes compared to probes that are more easily discernible. A perceptually difficult task presumably places greater demands on endogenous attention (Prinzmetal et al., 2009) and is more likely to prompt shifts of attention toward the probe (Weierich, Treat, & Hollingworth, 2008). Complementing studies of visual attention have demonstrated that discriminating between stimuli consumes more attentional resources and

requires longer processing time compared to responding to the location of a stimulus (Sagi & Julesz, 1985; Huang et al., 2007).

Affective cueing studies that have compared probe localisation and classification versions of the dot-probe paradigm have reported considerable differences in processing efficiency as a function of task requirements (Mogg & Bradley, 1999; Salemink, van den Hout, & Kindt, 2007). That is, participants who classified the probes made three times as many errors, and were ~200 ms slower in making their responses, compared to participants who responded to the probe's location. Additionally, ERP studies have shown that although both classification and detection tasks prompt increased P1 amplitudes at ~75-100 ms post-stimulus onset, corresponding to early processing in the visual cortex, classification tasks also potentiate the N1 component, which is comparatively weaker or absent in detection tasks (Mangun & Hillyard, 1991; Vogel & Luck, 2000). Whereas the P1 component is considered to reflect the directing of attention to a cued location, the N1 component has been interpreted as reflecting enhanced engagement of attention required to discriminate between the probes. Considered together, these findings provide further evidence that probe classification tasks place greater demands on attentional resources relative to probe localisation tasks.

Because participants must pay closer attention when classifying a probe compared to responding to its location, Klein (2000) proposed that they adopt a task set that is characterised by a higher degree of attentional control. That is, participants apportion and maintain greater attention to completing probe classification tasks than localisation tasks. Assuming that the task set cannot be changed during brief inter-stimulus intervals between the cue and probe, more attentional resources are available for processing the cues, in addition to the probes. Consequently, attention

may engage the cues more readily (Klein, 2000) and/or disengage slower during probe classification tasks (Lupiáñez et al., 2001) relative to less demanding localisation tasks. Increasing task demands by requiring participants to classify the probes may therefore enhance the SCT's sensitivity for detecting the effects of valence and arousal on attentional engagement and disengagement.

Due to the unexpected findings of a reverse cue validity effect in Study 2, parameters of the SCT were modified in the current study. Given that the use of a probe classification task may enhance the allocation of spatial attention, participants were required to discriminate between two possible probes rather than respond to its location. Additionally, to minimise spatial competition between the cues and probes on valid trials, the location of the probes was amended, such that they did not overlap with the cues. Cue duration was also manipulated to examine the time-course of attention for motivationally significant stimuli. On the basis of previous findings that nonselect participants allocate attention to threatening stimuli early in the information processing stream (Koster, Crombez et al., 2007), brief exposure conditions (≤ 100 ms) were employed in Experiments 3.1 and 3.2. The duration of cue exposure was increased to 100-400 ms in Experiment 3.3 to examine the influence of motivationally significant stimuli on spatial attention during comparatively later stages of processing. The ratio of valid to invalid trials was also varied between experiments, thereby manipulating the predictive validity of the cues. When the proportion of valid trials was 50%, the cues were non-predictive of the probe. Under this condition, attention for the pictures was assumed to be mediated by exogenous, stimulus-driven processes. In contrast, when the pictures were rendered task-relevant by increasing the proportion of valid trials to 75%,

endogenous processes were also assumed to operate to enhance attention for the cues. Variations in task parameters for Study 3 are summarised in Table 6.1.

Table 6.1

Variations in Parameters for the Spatial Cueing Task Administered in Study 3.

Experiment	Cue Validity	Exposure Conditions
Experiment 3.1	50:50	24 ms, 59 ms, 100 ms*
Experiment 3.2	75:25	24 ms, 59 ms, 100 ms*
Experiment 3.3	75:25	100 ms*, 200 ms, 400 ms

Note. *Due to the refresh rate of the monitor (85 Hz), the exact duration of stimulus exposure for the 100 ms exposure condition was 106 ms.

General Methodology

Participants

The current study adopted the same recruitment protocols employed in Study 2. The final samples were comprised of participants who reported heterosexual orientation and normal or corrected-to-normal vision. Across the three experiments, a total of 137 participants were recruited, 114 of whom were female (83.21%). The age of the combined sample varied between 18 and 56 years (M = 22.10 years, SD = 6.41). Seven participants reported that they were not attracted to members of the opposite sex (5.11%). Data obtained from these participants were removed prior to analysis.

Materials & Procedure

Spatial cueing task. Two modifications were made to the SCT, the first of which concerned how participants responded to the probe. On each trial, the offset of the cues was followed by either a black diamond (◆) or square (■), measuring 6 mm × 6 mm (subtending 0.6º × 0.6º). Participants were required to categorise the probe as quickly and accurately as possible. Manual responses were made by pressing the corresponding key on a Cedrus response box (RB-530). To facilitate responses, the keys were labelled according to the corresponding probe (◆ or ■). The two probe types appeared with equal frequency in each administration of the task. In addition to adopting a probe classification task, the location of the probes was also adjusted to minimise spatial competition with the cues. Rather than appearing in the centre of the placeholder boxes, probes were presented 1.00 cm (1.0º) from either the left edge of the left placeholder box or the right edge of the right placeholder box. With this exception, the arrangement of the stimuli and placeholder boxes was identical to Study 2. Further details regarding the display layout are provided in Appendix F. The time-course of each trial was also consistent with Study 2, except for the exposure duration of the cues, which was manipulated within each experiment. An example of a valid trial on the SCT is depicted in Figure 6.1.

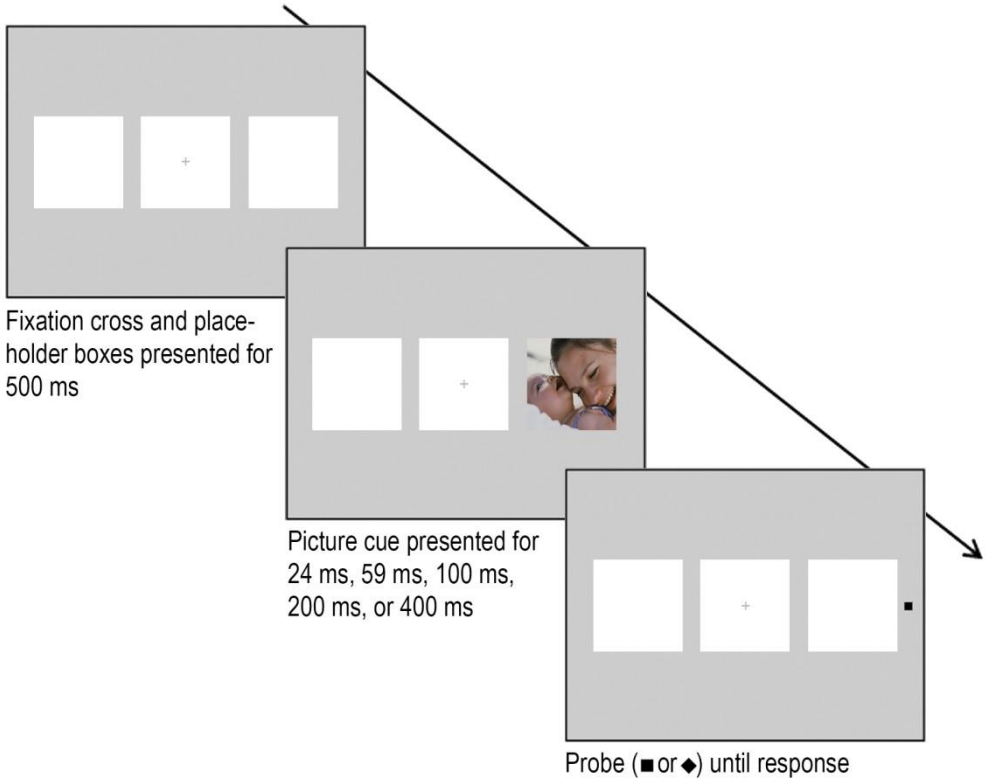

Figure 6.1. An example of a valid trial on the spatial cueing task in Study 3. During invalid trials, the picture cue and the probe appeared in opposite spatial locations.

As in Study 2, the SCT included four blocks of 72 test trials, equating to 288 trials in total. No changes were made with respect to the picture stimuli that served as cues or their frequency of exposure. A parallel approach to counterbalancing was also adopted, with the addition that each probe type appeared with equal frequency within each block of trials. Importantly, all pictures were presented equally often to the left and right placeholder boxes in each exposure condition. Each picture served as a valid cue on either 50% (Experiment 3.1) or 75% (Experiments 3.2 & 3.3) of trials in which it was used, corresponding to the ratio of valid to invalid trials. Cue type, exposure duration, and location were quasi-randomised within each trial sequence, with no more than two consecutive presentations of the same cue type and no more than three successive presentations to the same location or for the same

duration. Because accurate responding on the probe classification task necessitated that participants attend to and process the probes, the inclusion of catch trials was unnecessary. However, in the interests of maintaining methodological consistency with Study 2, six catch trials were included in each block of trials, as described in the General Methodology for Study 2.

Prior to commencing the first block of test trials, participants completed 24 practice trials to familiarise them with the nature of the probe classification task. During these trials, onscreen text provided participants with feedback (*correct* or *incorrect*), which appeared at the top of the display. Feedback was not provided during the test trials.

With the exception of key modifications to the SCT, all materials and procedures were the same as those employed in Study 2. Participants completed both scales of the STAI (Spielberger et al., 1983) prior to the first block of trials. Following completion of the SCT, participants rated all of the pictures in terms of pleasure and arousal. Further details regarding the picture rating procedure can be found in the General Methodology for Study 2.

Design

The experimental design was identical to Study 2, consisting of a 2 × 2 × 2 × 3 repeated-measures design. The independent factors were valence (threatening vs. appetitive), arousal (low vs. high), validity (valid vs. invalid) and exposure duration (24 ms vs. 59 ms vs. 100 ms [Experiments 3.1 & 3.2], and 100 ms vs. 200 ms vs. 400 ms [Experiment 3.3]), which were varied within-subjects. The dependent variable was RT for correctly indicating the type of probe. Accuracy was also recorded as a measure of task performance. To control for individual differences in

state and trait anxiety, scores obtained on the STAI-S and STAI-T were included as covariates.

Data Preparation & Analysis

A parallel approach to data analysis was employed. The RT data were cleaned using the same procedures described for Study 2 and subjected to a 2 × 2 × 2 × 3 repeated-measures ANCOVA to determine the individual and combined effects of valence (threatening vs. appetitive), arousal (low vs. high), validity (valid vs. invalid), and exposure duration (24 ms vs. 59 ms vs. 100 ms [Experiments 3.1 & 3.2] and 100 ms vs. 200 ms vs. 400 ms [Experiment 3.3]), after controlling for STAI-S and STAI-T scores. Significant interactions involving cue type were followed-up using CVIs ($RT_{Invalid\ Cue} - RT_{Valid\ Cue}$). In the event that higher-order interactions involving cue validity, valence and arousal were significant, indices of attentional engagement and disengagement were calculated for each cue type:

$$\text{Engagement Index} = RT_{Valid/Neutral\ Cue} - RT_{Valid/Motivationally\ Significant\ Cue}$$

$$\text{Disengagement Index} = RT_{Invalid/Motivationally\ Significant\ Cue} - RT_{Invalid/Neutral\ Cue}$$

Engagement indices greater than zero reflected facilitated engagement of that cue type relative to the neutral pictures, whereas values less than zero were indicative of avoidance. For disengagement indices, positive values demonstrated that attention was slow to disengage from the cues, whereas negative values indicated speeded disengagement compared to the neutral pictures. Single sample *t*-tests were performed to compare engagement and disengagement indices against zero, which reflected no difference from neutral. All statistical tests adopted an alpha

level of $p < .05$. Bonferroni corrected p values have been reported for all *a priori* and post-hoc follow-up tests.

Experiment 3.1

In earlier studies that have employed probe classification tasks with nonselect samples, delayed disengagement from pictures of attractive members of the opposite sex has been reported, in the absence of facilitated engagement (Koranyi & Rothermund, 2012; Maner, Gailliot, & DeWall, 2007; Maner, Gailliot, Rouby et al., 2007). In these studies, however, cues were exposed for 500 ms prior to probe onset, thus allowing ample time for attention to shift away from the cued location (Weierich et al., 2008). A meta-analysis of studies examining attention for positive stimuli has shown that initial orienting to cued locations is enhanced for appetitive pictures relative to neutral pictures, with effects attenuating in conditions that allow for multiple shits of attention (i.e., > 250 ms; Pool et al., 2016). These data raise the possibility that facilitated engagement of appetitive stimuli may have occurred in previous spatial cueing studies, but terminated prior to the onset of the probe.

Examining the time-course of attention to threatening pictures in non-anxious participants, Koster, Crombez et al. (2007) observed faster responding to probes that were validly cued by HAT pictures compared to neutral pictures. In contrast, less arousing threatening pictures did not attract facilitated engagement. Although this finding shows that facilitated engagement of highly threatening stimuli can occur in non-anxious individuals, the effect was limited to when the cues were exposed for 100 ms, suggesting that enhanced attention for threat terminated during very early stages of processing. Facilitated engagement of threat-relevant stimuli has also been observed under conditions that restrict conscious processing of the cues. In a dot-probe study by Carlson and Reinke (2008), emotive faces were presented for 33 ms

and followed by a visual mask that inhibited perceptual awareness. Nonselect participants were found to respond faster to probes that replaced fearful faces compared to neutral faces, indicating that spatial attention was facilitated by the fearful expressions. Although these results converge with ERP data, which have revealed rapid cortical processing of affective pictures (Junghöfer et al., 2001; Sass et al., 2010; Schupp, Junghöfer et al., 2004; Smith et al., 2003), the arousal value of the stimuli was not accounted for.

Independent of valence, stimulus arousal has been shown to modulate ERP components that index early processing in the extrastriate visual cortex (Olofsson et al., 2008; Sass et al., 2010; Schupp, Flaisch, Stockburger, & Junghöfer, 2006). Schupp, Junghöfer et al. (2004) found that early posterior negativity was especially pronounced for pictures of erotic couples compared to aversive and less arousing pictures. This finding suggests that early allocation of attention to emotional stimuli could be particularly sensitive to stimulus arousal. That is, facilitated engagement may occur for high arousing stimuli of either a threatening or appetitive valence, provided they are presented under conditions that capture early stages of processing.

Experiment 3.1 was optimised to detect facilitated engagement by adopting an equal ratio of valid to invalid trials, coupled with brief exposure durations ($\leq$ 100 ms). Employing a stimulus set varying in both valence and arousal, the current experiment aimed to determine whether spatial orienting to affective stimuli is facilitated on the basis of threat or arousal, after controlling for individual differences in state and trait anxiety. Hypotheses paralleled those of Experiment 2.3. Given the change in task demands and elimination of spatial overlap between the cues and probes, a positive cue validity effect was again predicted, with responses facilitated by valid cues and slowed by invalid cues. An interaction between valence,

arousal, and validity was also hypothesised. In accordance with the assumptions of threat-superiority models (Beck & Clark, 1997; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Öhman, 1996; Öhman & Mineka, 2001), potentiation of the cue validity effect was expected for threatening pictures compared to appetitive pictures. Consistent with the findings reported by Koster, Crombez et al. (2007), the HAT cues were predicted to prompt facilitated engagement, with faster responses to validly cued probes preceded by pictures of mutilated bodies and blood injuries compared to the neutral pictures.

Alternative hypotheses were made according to motivational significance theory and the arousal hypothesis (Bradley & Lang, 2007; Lang et al., 1997, 1998; Schimmack, 2005). Assuming that stimulus arousal underlies the orienting of attention, a larger cue validity effect was predicted for high arousing pictures compared to low arousing pictures. On the basis of findings that early cortical responses are enhanced for erotic pictures (Schupp, Junghöfer et al., 2004), facilitated engagement of the HAA stimuli was anticipated, with faster responses on valid trials following the presentation of pictures depicting heterosexual erotica compared to neutral pictures.

With respect to time-course, facilitated engagement is assumed to occur preconsciously, during automatic stages of processing (Cisler & Koster, 2010; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Öhman, 1996; Williams et al., 1988, 1997). Therefore facilitated attentional engagement of the motivationally significant stimuli was expected to occur even under very brief exposure conditions that limit conscious awareness of the cues' content (i.e., 24 ms). Given the equal ratio of valid to invalid trials and the brief duration of cue exposure, classification latencies were considered to be uninfluenced by endogenous attention that operates

during later stages of processing. Assuming that delayed disengagement from affective stimuli requires some degree of strategic processing, as proposed by Cisler and Koster (2010), disengagement was not expected to be affected by either valence or arousal.

Method

Participants

Fifty-one participants were sampled for Experiment 3.1. Four participants (7.84%) indicated that they did not consider members of the opposite sex to be sexually appealing and their data were excluded. The retained sample of 47 included 38 females (80.85 %). The age of the participants varied between 18 and 42 years (*M* = 21.51 years, *SD* = 5.46). State anxiety scores derived from the STAI ranged from 20 to 51 (*M* = 32.38, *SD* = 7.57). Trait anxiety scores ranged from 23 to 61 (*M* = 38.49, *SD* = 9.70).

Materials & Procedure

Consistent with Experiment 2.3, cues were exposed for 24 ms, 59 ms, and 100 ms, thereby probing very early stages of attentional processing. An equal ratio of valid to invalid trials was also adopted, which has been noted to enhance sensitivity for detecting facilitated engagement effects (Koster, Crombez et al., 2007).

Three trial sequences were developed to ensure that each picture was presented with equal frequency to the left and right placeholder boxes in each exposure condition, while serving as both a valid and invalid cue. These sequences were reversed to produce a total of six presentations orders, which were assigned to participants according to the order in which they completed the experiment. For each trial sequence, cue type, exposure duration, and location were quasi-randomised, as reported in the General Methodology. Before each block of trials, onscreen text

advised participants that the cues would accurately indicate the location of the probe "some of the time, but not all of the time."

Results

Data Preparation

Two participants' data were removed due to an outlying proportion of incorrect responses (47.90% and 50.70% of test trials). Data from two additional participants were also discarded due to delayed responding (RTs > 750 ms) on 58.38% and 44.43% of test trials. The mean proportion of incorrect responses for the remaining 43 participants was 4.85%. These data were removed prior to analysis, as were responses occurring earlier than 150 ms and later than 750 ms (11.58%). Outliers were also removed on a case-by-case basis, defined as RTs exceeding ± 2 *SD*s from a participant's mean RT for each experimental condition (0.71%). Statistical analyses were performed on 82.86% of the data from the retained cases (N = 43).

Statistical Assumptions

The statistical assumptions of ANCOVA were assessed using the same methods employed in Study 2. To screen for univariate outliers, standardised RTs were calculated and compared against $z = \pm 3.29$ ($p < .001$). No outliers were detected, which was corroborated by box-and-whiskers plots. Frequency histograms and normal quantile-quantile plots indicated that the RT data were normally distributed within each experimental condition. Standardised skewness and kurtosis values were nonsignificant at $z = \pm 2.58$ ($p < .01$), confirming that the assumption of normality was met. Mauchly's test of sphericity was nonsignificant for all mains effects and interactions.

Catch Trials

None of the retained participants responded to any of the catch trials. Given the nature of the task, this result was not unexpected and indicates that participants attended to and processed the probes before making their responses.

Accuracy Data

The proportion of correct responses ranged from 87% to 99% of trials (*M* = 95%, *SD* = 2.57). Due to the low frequency of errors, analysis of the accuracy data did not yield meaningful results.

Reaction Time Data

Overall effects. Mean RTs for probes preceded by each cue type as a function of cue validity and exposure condition are presented in Table 6.2. These data were entered into a 2 × 2 × 2 × 3 repeated-measures ANCOVA to determine the effects of valence (threatening vs. appetitive), arousal (low vs. high), validity (valid vs. invalid), and exposure duration (24 ms vs. 59 ms vs. 100 ms) on probe classification latencies, after adjusting for STAI-S and STAI-T scores.

Table 6.2

Mean Response Times (ms), Standard Deviations (SD), and Cue Validity Indices (CVI) as a Function of Cue Type, Validity and Exposure Duration in Experiment 3.1.

		Exposure Condition								
		24 ms			59 ms			100 ms		
Cue Type	Cue Validity	*M*	*SD*	CVI	*M*	*SD*	CVI	*M*	*SD*	CVI
Low Arousing Threatening	Valid	552	60	-1	543	54	23	521	54	62
	Invalid	551	57		565	55		583	49	
Low Arousing Appetitive	Valid	546	50	16	557	48	2	533	58	42
	Invalid	563	51		559	56		576	41	
High Arousing Threatening	Valid	541	48	29	552	64	27	538	60	54
	Invalid	570	62		579	52		592	56	
High Arousing Appetitive	Valid	557	47	-4	539	49	32	522	64	56
	Invalid	553	55		572	53		578	55	
Neutral	Valid	553	43	6	534	56	32	523	49	60
	Invalid	558	44		567	45		583	39	

Results of the omnibus ANCOVA revealed that STAI-S and STAI-T scores did not interact with cue valence or arousal and were nonsignificant covariates, Fs < 1. After controlling for state and trait anxiety, a positive cue validity effect was found, characterised by faster RTs for probes preceded by valid cues (M = 542 ms, SE = 6.84) than invalid cues (M = 570 ms, SE = 5.85), $F(1, 40) = 64.54$, MSE = 3191.49, $p < .001$, $\eta_p^2 = .62$. This result demonstrates that attention was generally directed towards the pictures at the time of probe onset.

RTs were significantly affected by a two-way interaction between valence and arousal, $F(1, 40) = 7.99$, MSE = 1086.43, $p = .007$, $\eta_p^2 = .17$. The interaction between validity and exposure duration was also significant, $F(2, 80) = 25.85$, MSE = 1675.10, $p < .001$, $\eta_p^2 = .39$. These lower-order interactions were qualified by a four-way interaction between valence, arousal, validity, and exposure duration, $F(2, 80) = 5.82$, MSE = 1676.57, $p = .004$, $\eta_p^2 = .13$. All other main effects and interactions were nonsignificant, Fs ≤ 2.87, ps ≥ .098.

To decompose the nature of the four-way interaction, follow-up ANCOVAs were performed at each level of exposure duration, with valence, arousal and validity as factors. STAI-S and STAI-T scores were included as covariates in each of the subsequent analyses and were nonsignificant, Fs < 1. In the event that valence and arousal interacted with cue validity, CVIs ($RT_{Invalid\ Cue} - RT_{Valid\ Cue}$) were calculated as a general measure of attention for the different cue types. CVIs obtained by the neutral cues were then subtracted from the CVIs calculated for the other cue types in order to determine the relative effects of valence and arousal. Values larger than zero were reflective of enhanced attention for that cue type relative to neutral, whereas values less than zero were indicative of avoidance.

24 ms. A positive cue validity effect was observed when the cues were exposed for 24 ms, with significantly faster RTs for valid trials (M = 549 ms, SE = 6.68) relative to invalid trials (M = 559 ms, SE = 7.00), $F(1, 40) = 5.78$, MSE = 1541.32, $p = .021$, $\eta_p^2 = .13$. Although the main effects of valence and arousal were nonsignificant, Fs < 1, a significant Valence × Arousal × Validity interaction was observed, $F(1, 40) = 8.03$, MSE = 1706.17, $p = .007$, $\eta_p^2 = .17$, reflecting a combined effect of valence and arousal on attentional orienting.

Cue validity indices. Using RTs obtained in the 24 ms exposure condition, CVIs ($RT_{Invalid\ Cue} - RT_{Valid\ Cue}$) for the neutral cues were deducted from CVIs calculated for each of the other cue types. These values were used to determine the effect of cue arousal on attention at each level of valence. As can be seen in Figure 6.2, when the probes were cued by threatening pictures, CVIs were larger for high arousing cues (M = 24, SE = 9.88) compared to low arousing cues (M = -7, SE = 10.88), $F(1, 40) = 5.07$, MSE = 3859.90, $p = .030$, $\eta_p^2 = .11$. In contrast, there was no significant difference in CVIs for the low (M = 11, SE = 8.02) and high arousing appetitive cues (M = -10, SE = 10.30), $F(1, 40) = 3.34$, MSE = 2653.81, $p = .075$, $\eta_p^2 = .08$.

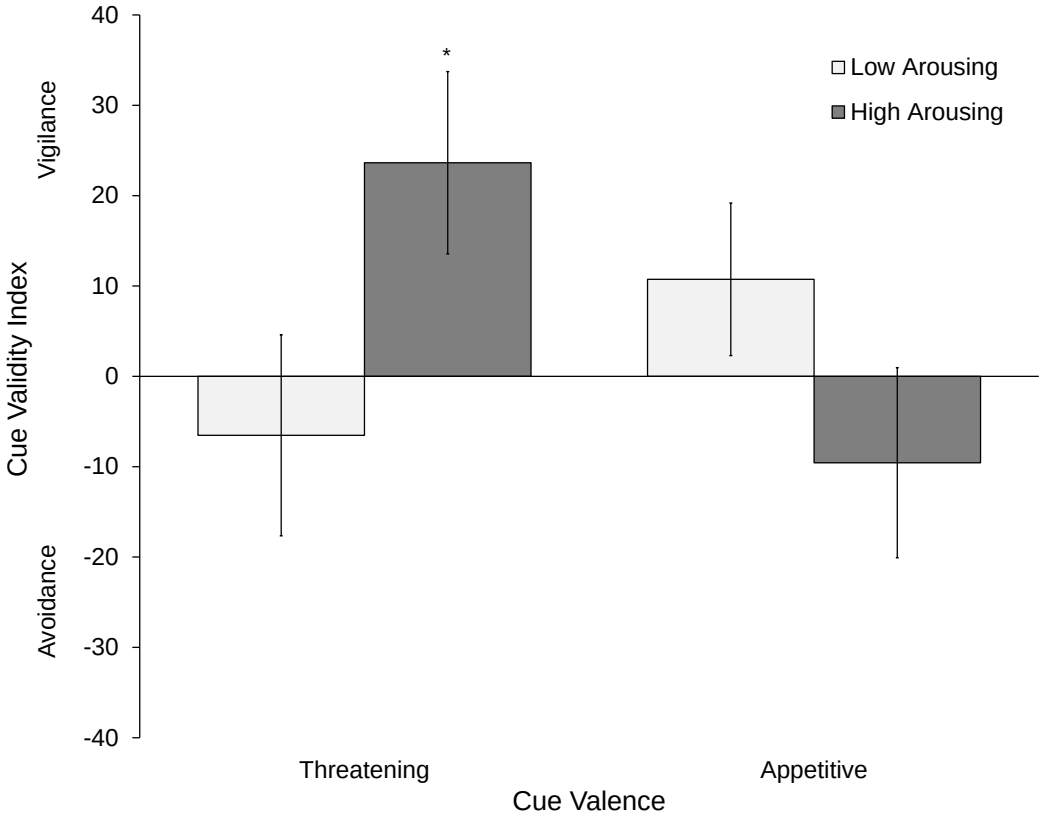

Figure 6.2. Cue validity indices in the 24 ms exposure condition as a function of cue valence and arousal (Experiment 3.1). Zero = no difference from the neutral cues. Error bars = standard errors. * denotes significant difference from zero, $p < .05$.

Single sample *t*-tests were performed to compare CVIs obtained in the 24 ms exposure condition against zero, which reflected no difference from the neutral cues. The HAT cues obtained a CVI that was significantly greater than zero, $t(42) = 2.34$, $p = .024$, $d = 0.36$, indicating that they attracted enhanced attention. All other comparisons against zero were nonsignificant, $ts \leq 1.27$, $ps \geq .210$.

Attentional bias indices. To determine how the distinct components of attentional orienting were affected by valence and arousal at 24 ms post-stimulus onset, indices of attentional engagement and disengagement were calculated for each cue type. Engagement indices were calculated from RTs to validly cued probes by deducting RTs on trials employing the motivationally significant cues from RTs on

neutral trials. Positive values reflected facilitated engagement relative to the neutral pictures, whereas negative values were indicative of avoidance. Disengagement indices were calculated using RTs to invalidly cued probes, with RTs on neutral trials subtracted from RTs following motivationally significant cues. Positive values demonstrated that attention was slow to disengage from the cues, while negative values indicated accelerated disengagement compared to the neutral pictures.

As shown in Figure 6.3, the HAT cues obtained engagement indices that were significantly greater than zero ($M = 12$, $SD = 35$), $t(42) = 2.25$, $p = .030$, $d = 0.34$, consistent with facilitated attentional engagement. Engagement indices obtained by the other types were not significantly different from zero, $ts \leq 1.23$, $ps \geq .227$. Disengagement indices did not vary significantly from zero for any of the motivationally significant cue types, $ts \leq 1.41$, $ps \geq .166$.

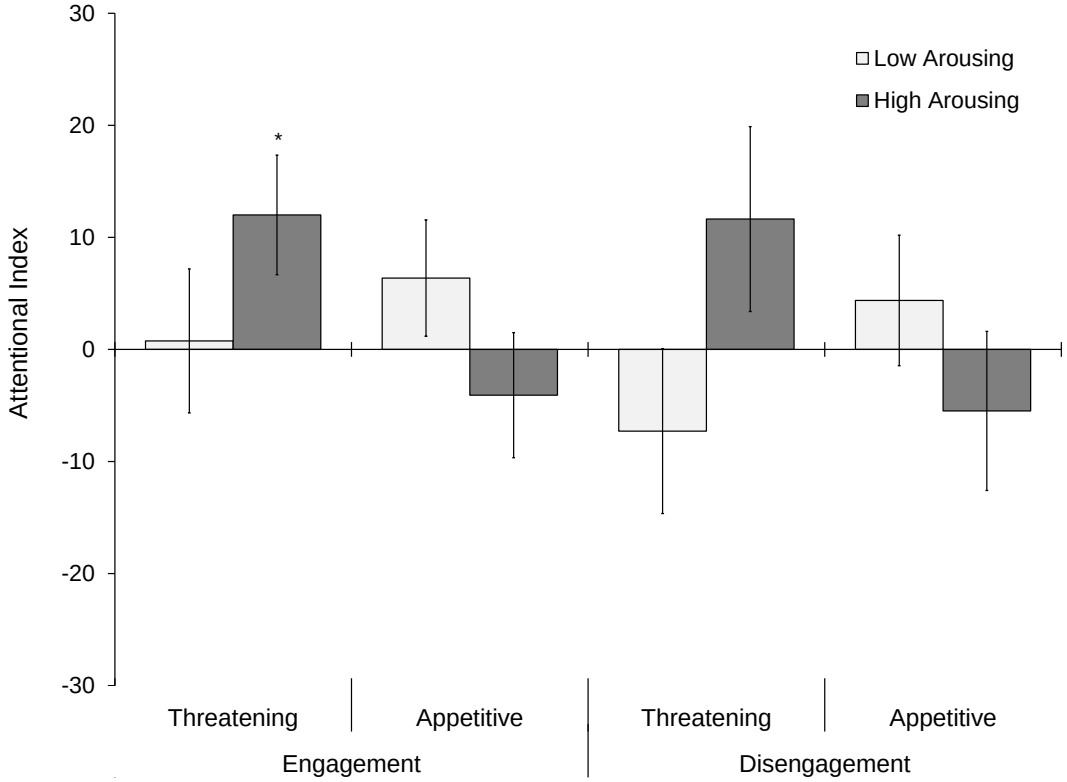

Figure 6.3. Indices of attentional engagement and disengagement as a function of valence and arousal in the 24 ms exposure condition (Experiment 3.1). Zero = no difference from the neutral cues. Error bars = standard errors. * denotes significant difference from zero, $p < .05$.

59 ms. A significant cue validity effect was observed in the 59 ms exposure condition, with faster responding on valid trials (M = 548 ms, SE = 6.80) than invalid trials (M = 569 ms, SE = 6.34), $F(1, 40) = 19.64$, $MSE = 1971.17$, $p < .001$, $\eta_p^2 = .33$. The main effects of valence and arousal were nonsignificant, Fs < 1. A significant Arousal × Validity interaction revealed that attention for the cues varied as a function of arousal, $F(1, 40) = 4.63$, $MSE = 1411.26$, $p = .038$, $\eta_p^2 = .10$. All other interactions were nonsignificant, Fs ≤ 3.68, ps ≥ .062.

Cue validity indices. To follow-up the Arousal × Validity interaction, CVIs were calculated for the low and high arousing cue types, after averaging over valence. As can be seen in Figure 6.4, the high arousing cues (M = -2, SE = 6.69) obtained larger CVIs compared to the low arousing cues (M = -20, SE = 9.00), F(1, 40) = 4.63, MSE = 1411.26, p = .038, η_p^2 = .10. This finding demonstrates that attention oriented more readily to the high arousing pictures in the 59 ms exposure condition. Comparisons against zero revealed that CVIs for the low arousing cues were significantly below zero, t(42) = 2.23, p = .031, d = 0.34, indicating that attention favoured the neutral pictures. CVIs for the high arousing cues did not vary significantly from zero, t < 1.

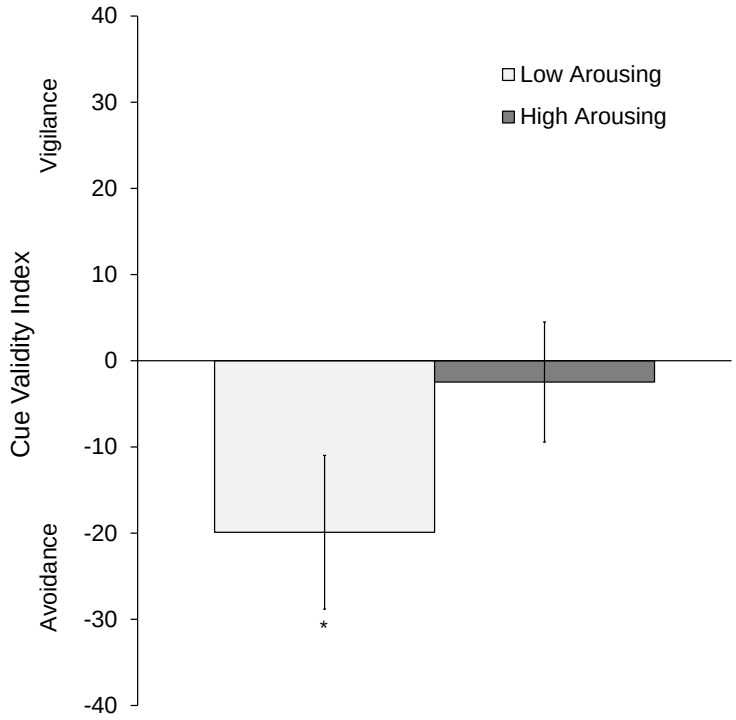

Figure 6.4. Cue validity indices in the 59 ms exposure condition as a function of cue arousal (Experiment 3.1). Zero = no difference from the neutral cues. Error bars = standard errors. * denotes significant difference from zero, p < .05.

Attentional bias indices. To examine the effects of cue arousal on the components of spatial attention at 59 ms post-stimulus onset, indices of attentional engagement and disengagement were calculated for the low and high arousing cues types, averaging over valence. As shown in Figure 6.5, comparisons against zero revealed that engagement indices for the low arousing cues (M = -15, SD = 46) were significantly below zero, $t(42) = 2.20$, $p = .034$, $d = 0.34$, consistent with attentional avoidance. The negative engagement indices obtained by the high arousing cues also neared significance (M = -11, SD = 37), $t(42) = 1.98$, $p = .055$, $d = 0.30$. Indices of disengagement did not vary significantly from zero for either the low or high arousing cues, ts ≤ 1.84, ps ≥ .073.

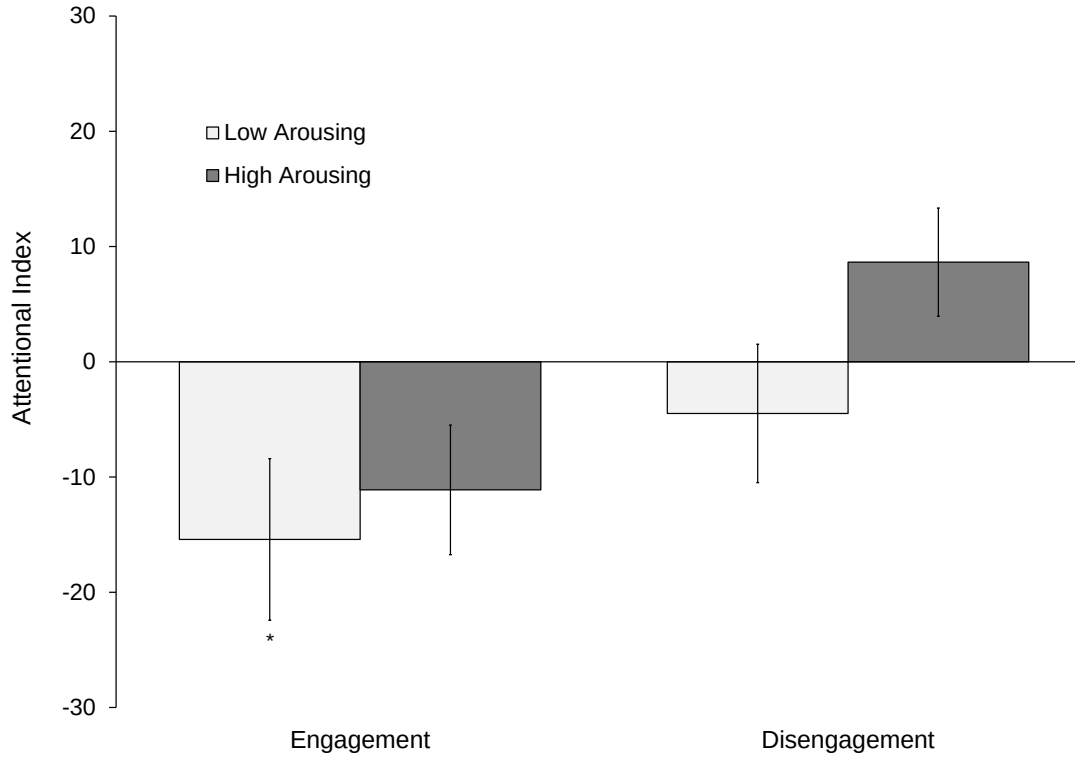

Figure 6.5. Indices of attentional engagement and disengagement for the low and high arousing cues in the 59 ms exposure condition (Experiment 3.1). Zero = no difference from the neutral cues. Error bars = standard errors. * denotes significant difference from zero, $p < .05$.

100 ms. Analysis of the RT data obtained in the 100 ms exposure condition revealed a strong cue validity effect, $F(1, 40) = 80.87$, $MSE = 3029.20$, $p < .001$, $\eta_p^2 = .67$, characterised by faster responses on valid trials ($M = 529$ ms, $SE = 8.00$) than invalid trials ($M = 582$ ms, $SE = 5.90$). Although the main effects of valence and arousal were nonsignificant, Fs ≤ 2.94, ps $\geq .094$, a significant Valence × Arousal interaction was observed. As shown in Figure 6.6, cue arousal had a significant effect on RTs when the probes were preceded by threatening pictures, $F(1, 40) = 5.33$, $MSE = 698.91$, $p = .026$, $\eta_p^2 = .12$, with slower responses following high arousing cues ($M = 565$ ms, $SE = 7.59$) compared to low arousing cues ($M = 552$ ms, $SE = 6.59$). In contrast, when the probes followed appetitive pictures, there was no significant difference in RTs between the low ($M = 554$ ms, $SE = 6.68$) and high arousing cues ($M = 550$ ms, $SE = 8.07$), $F < 1$. All other interactions in the 100 ms exposure condition were nonsignificant, Fs ≤ 1.74, ps $\geq .195$. Because neither valence nor arousal interacted with validity, analysis of the CVIs and attentional indices was unwarranted.

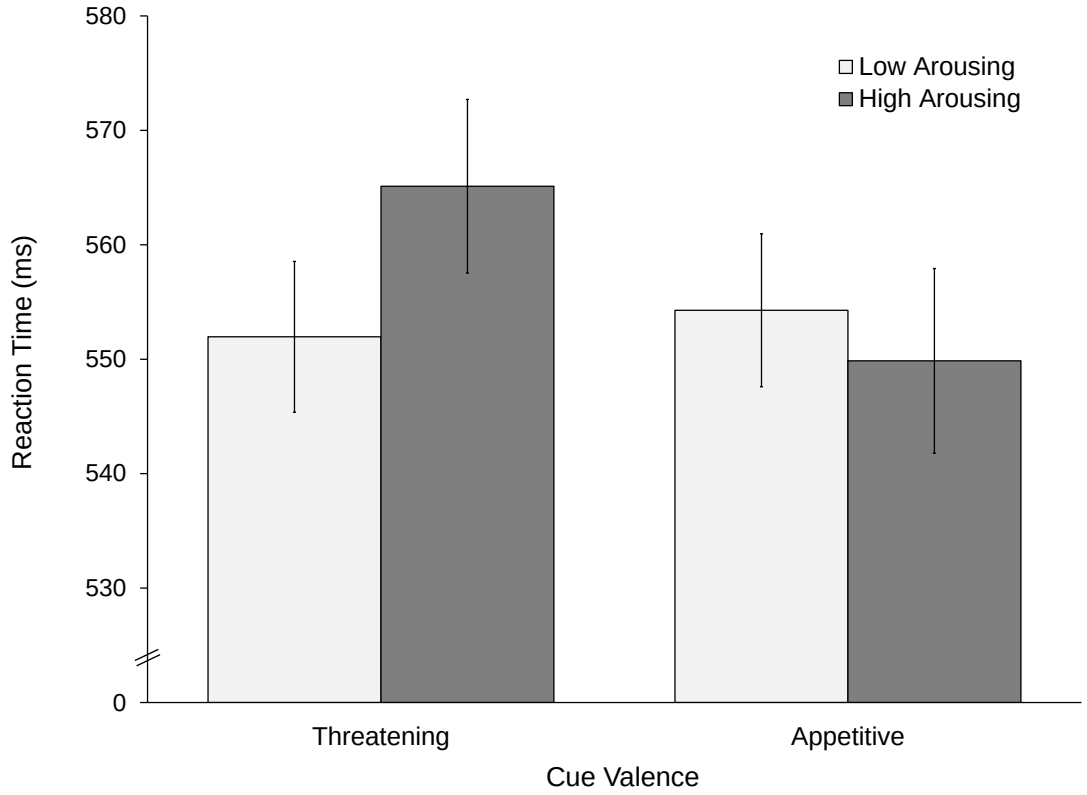

Figure 6.6. Mean RTs as a function of valence and arousal in the 100 ms exposure condition (Experiment 3.1). Error bars = standard errors.

Discussion

As predicted, the results revealed a positive cue validity effect, with faster responding on valid trials than invalid trials. This finding confirms that participants' attention was oriented to the cues, which facilitated responses to probes appearing in the same location (valid trials). When the probes appeared in the location opposite to cue (invalid trials), however, attention needed to shift before the probe could be processed, thereby incurring an increase in response time. As hypothesised, the effect of cue validity was found to vary as a function of both valence and arousal, in addition to exposure duration, indicating that attentional orienting was influenced by the affective qualities of the pictures during early stages of processing.

At 24 ms, attention for the cues was modulated by an interaction between stimulus valence and arousal. In partial support of threat-specific models (Beck & Clark, 1997; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Öhman, 1996; Öhman & Mineka, 2001; Williams et al., 1988, 1997), enhanced attention was observed for the HAT pictures, as indicated by a positive CVI. Consistent with the cognitive-motivation model (Mogg & Bradley, 1998), the current findings demonstrate that attention does orient to threatening stimuli in nonselect participants, but only when stimulus arousal is high. In contrast, the less arousing threat stimuli did not appear to attract preferential attention relative to the neutral pictures, as indicated by a nonsignificant CVI. These results show that the threshold for determining the severity of threatening material is sensitive to stimulus arousal, which is consistent with the assumption that arousal underlies activation of the defensive motivational system (Bradley, 2009; Bradley & Lang, 2007; Lang et al., 1997, 1998).

In agreement with threat-specific models (Beck & Clark, 1997; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Öhman, 1996; Öhman & Mineka, 2001), engagement indices were potentiated for the HAT cues in the 24 ms exposure condition, with faster responding to validly cued probes preceded by pictures of mutilated bodies and blood injuries compared to neutral pictures. Facilitated engagement of the HAT stimuli is partially consistent with findings reported by Koster, Crombez et al. (2007), who also observed an engagement bias for highly threatening pictures. Unlike the current experiment, however, facilitated engagement effects in their study were absent at 28 ms post-stimulus onset, and only emerged following 100 ms of cue exposure. Koster, Crombez et al. (2007) claimed that 28 ms may not allow sufficient time for the threatening features to be extracted from a

visual stimulus. The current findings, however, suggest that attentional engagement of threatening stimuli can occur rapidly, within 24 ms of stimulus onset. An important methodological distinction is that the HAT pictures employed by Koster, Crombez et al. (2007) included ontogenetic threats (i.e., guns and knives), whereas the threatening stimuli used in the present study were selected to be symbolic of phylogenetic threats to survival.

Elevated engagement indices for the HAT cues cannot be attributed to non-spatial interference or response slowing. If this were the case, comparable RTs would have been observed on both valid and invalid trials employing the HAT pictures. Moreover, because the ratio of valid to invalid trials was 50:50, there was no strategic incentive to attend to the pictures. Considering the irrelevance of the cues to the probe classification task, in addition to the very brief duration of cue exposure, preferential engagement of the HAT pictures at 24 ms post-stimulus onset appears to reflect an automatic, exogenous process that occurred independently of participants' intentions. This interpretation is consistent with the assumption that an attentional bias for threat occurs automatically, during preconscious stages of processing (Cisler et al., 2009; Cisler & Koster, 2010; Mogg & Bradley, 1998; Öhman, 1996; Williams et al., 1988, 1997), and converges with fMRI studies that have found heightened activation of the amygdala in response to masked fearful faces (Carlson et al., 2009; Whalen et al., 1998). Facilitated engagement of the HAT stimuli also occurred over and above individual differences in state and trait anxiety, which were statistically controlled. Results from the 24 ms exposure condition therefore provide strong support for the evolved fear module, which is assumed to facilitate rapid and preferential orienting to biologically-prepared threats during

preattentive stages of processing in all individuals, regardless of anxiety (Öhman, 1996; Öhman & Mineka, 2001).

At 59 ms post-stimulus onset, attention for the cues varied as a function of stimulus arousal. Analysis of the CVIs indicated that attention oriented more readily to the neutral pictures compared to low arousing pictures depicting childrearing and interpersonal aggression. Negative engagement indices further suggest that attention avoided the low arousing pictures. In contrast, there was no significant difference in attentional orienting to the high arousing and neutral pictures. Because the cues did not predict the location of the probes above chance, and were therefore task-irrelevant, attention may have inhibited processing the low arousing pictures in order to preserve performance on the probe classification task. This explanation is partially consistent with existing models, which propose that the allocation of attention to low or moderately threatening stimuli can be inhibited in non-anxious individuals (Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Williams et al., 1988, 1997). The current findings suggest, however, that attention for low or moderately arousing stimuli is inhibited, irrespective of valence. Considering the exposure duration of the cues, inhibited engagement of low arousing stimuli is assumed to have occurred quickly, within the first 59 ms following stimulus onset.

In the 100 ms exposure condition, a significant Valence × Arousal interaction revealed that cue valence moderated the effect of arousal on RTs. Specifically, probe classification latencies were slowed by the presentation HAT cues compared to LAT cues, whereas there was no difference in the speed of responding following the high and low arousing appetitive pictures. Importantly, the combined effect of valence and arousal was independent of cue validity and is therefore likely to reflect the influence of HAT pictures on non-spatial attentional factors, such as perceptual

competition or processing speed (cf. Bundesen, 1990; Pessoa, 2009), perhaps resulting from their preferential engagement during earlier stages of processing.

Contrary to the assumptions of motivational significance theory (Bradley & Lang, 2007; Lang et al., 1997, 1998), facilitated engagement was specific to HAT cues. The HAA pictures did not appear to attract preferential attention in any of the exposure conditions, which contrasts with findings of enhanced cortical reactivity to erotic pictures compared to threatening and less arousing pictures (Schupp, Junghöfer et al., 2004). Although the current data indicate that facilitated engagement is specific to HAT stimuli in nonselect participants, HAA stimuli may maintain attention by delaying disengagement.

Considering the SCT was designed to detect facilitated engagement effects by adopting an equal ratio of valid to invalid trials, the absence of delayed disengagement was not unexpected. When cues do not predict the location of the probes above chance, any observed effects are considered to reflect purely exogenous processes (Chica et al., 2014). Delayed disengagement, however, is considered to require some degree of strategic processing and is most reliably observed when the ratio of valid to invalid trials incentivises participants to maintain attention on the cued location (Cisler & Koster, 2010; Fox et al., 2001; Fox et al., 2002; Vogt et al., 2008). The absence of slowed disengagement from the motivationally significant pictures may therefore be attributed to the equal ratio of valid to invalid trials employed in the current experiment, which preluded the recruitment of top-down endogenous processes. By increasing the proportion of valid trials to 75%, endogenous processes that are responsive to the cues' predictive value may maintain attention on the cued location (Chica et al., 2014; Weierich et al., 2008).

Experiment 3.2

Previous spatial cueing studies that have compared anxious and non-anxious participants have identified difficulty disengaging attention from threatening stimuli as a cognitive marker of anxiety (Amir et al., 2003; Cisler & Olatunji, 2010; Fox et al., 2001; Fox et al., 2002; Georgiou et al., 2005; Koster, Crombez, Verschuere, Van Damme et al., 2006; Sheppes, Luria, Fukuda, & Gross, 2013; Van Damme et al., 2006; Yiend & Mathews, 2001). Although threatening stimuli may have greater motivational relevance to anxious individuals, other studies have found evidence of delayed disengagement from both threatening and appetitive stimuli in nonselect and low anxious participants (Koster, Crombez et al., 2007; Maner, Gailliot, & DeWall, 2007; Maner, Gailliot, Rouby et al., 2007; Massar et al., 2011; Koranyi & Rothermund, 2012; Sagliano, Trojano et al., 2014; Vogt et al., 2008). Assuming that arousal indexes the motivational significance of a stimulus (Bradley, 2009; Bradley & Lang, 2007), sufficiently arousing stimuli may hold attention and slow disengagement in all individuals, irrespective of valence.

As proposed by Koster, Crombez et al. (2007), disengagement effects are more readily observed when participants are encouraged to attend to a cued location. Therefore, to increase the SCT's sensitivity for detecting delayed disengagement effects, the predictive value of the cues was enhanced in the current experiment by increasing the proportion of valid trials to 75%. When a high proportion of valid trials are employed, directing attention towards the cued location offers a strategic advantage, since this is where the probe is most likely to appear on each trial (Shaw & Shaw, 1977). Therefore, under conditions that enhance the predictive value of the cues, results are considered to reflect a combination of endogenous attention and

bottom-up, exogenous processes (Chica et al., 2014; Lupiáñez et al., 2004; Prinzmetal et al., 2005; Weierich et al., 2008).

In non-emotional versions of the SCT, predictive cues have been shown to enhance probe classification accuracy on valid trials relative to invalid trials, whereas non-predictive cues do not (Prinzmetal et al., 2005). On the basis of these findings, Prinzmetal et al. (2005) proposed that cues strengthen perpetual representations of stimuli appearing in attended locations, but only if they predict the location of the probe on the majority of trials. In the context of a probe classification task, predictive cues may promote endogenous attention to enhance perceptual processes needed to discriminate between the probes (Prinzmetal et al., 2005; Prinzmetal et al., 2009).

Due to the predictive value of the cues, an effect of cue validity was predicted, with faster responding on valid trials than invalid trials. The positive cue validity effect was hypothesised to be qualified by a significant four-way interaction between valence, arousal, validity, and exposure duration. In line with threat-superiority models (Beck & Clark, 1997; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Öhman, 1996; Öhman & Mineka, 2001; Williams et al., 1988, 1997), potentiation of the cue validity effect was expected for threatening pictures compared to appetitive pictures. Alternatively, based on the assumption that endogenous attention is influenced by motivational significance (Bradley & Lang, 2007; Lang et al., 1997, 1998), cue validity was predicted to interact with arousal, with the high arousing pictures eliciting a stronger cue validity effect compared to the low arousing pictures, independent of valence.

In terms of the specific components of attentional orienting, disengagement was expected to be influenced by the motivationally significant cues. When the cues

and probes appeared in opposite peripheries (i.e., invalid trials), RTs were considered to index the speed with which attention was able to disengage the pictures before shifting towards the location of the probe. Assuming that delayed disengagement occurs exclusively for intensely threatening stimuli (Koster, Crombez et al., 2007), slower responses were predicted for invalidly cued probes preceded by pictures depicting human mutilations and blood injuries compared to neutral pictures. In contrast, the arousal hypothesis predicted that the speed of disengagement would vary as a function of stimulus arousal (Vogt et al., 2008), with the high arousing pictures producing slower responses on invalid trials compared to the neutral pictures. The same exposure conditions employed in Experiment 3.1 (24 ms, 59 ms, and 100 ms) were adopted in the current experiment so that any change in results could be attributed to endogenous attention arising from the predictive value of the cues. Because delayed disengagement is assumed to rely on some degree of strategic processing (Cisler & Koster, 2010), disengagement effects were expected to occur when the cues were presented for 100 ms, and therefore most likely to exceed participants' threshold of awareness.

Method

Participants

A sample of 42 participants was recruited for Experiment 3.2. Data from one participant (2.38 %), who reported a homosexual orientation, was removed. The remaining participants included 32 females (78.05%) and were aged between 18 and 49 years (M = 22.59 years, SD = 7.27). Scores obtained on the STAI-S ranged from 20 to 59 (M = 30.56, SD = 7.83), while STAI-T scores ranged from 20 to 65 (M = 36.22, SD = 9.00).

Materials & Procedure

The SCT was identical to Experiment 3.1, with the exception of the ratio of valid to invalid trials, which was increased to 75:25. Each picture therefore served as a cue on three times as many valid trials than invalid trials. Six trial sequences were developed to ensure that, across the sample, all pictures were presented equally often to the left and right placeholder box at each exposure duration, while serving as both a valid and invalid cue. These orders were reversed to produce a total of 12 trial sequences, which were assigned to participants according to the order in which they arrived at the laboratory. Prior to the commencement of each block of trials, participants were informed that "the pictures [would] appear in the same location as the diamond or square on *most*, but not all, trials."

Results

Data Preparation

One participant was found to have made incorrect responses on 20.50% of test trials and their data was removed. For the remaining cases, RTs corresponding to incorrect responses were discarded (5.13% of trials). A second case was removed due to delayed responding (RTs > 750 ms) on 40.27% of test trials. For each condition, RTs falling outside of ± 2 *SD*s from each participant's mean RT were also removed (1.15%). Analyses were performed on 87.52% of the data obtained from the final sample ($N = 39$).

Statistical Assumptions

The RT data satisfied the assumptions of ANCOVA. Standardised RTs did not exceed $z = \pm 3.29$ ($p < .001$), indicating an absence of univariate outliers, which was confirmed via visual inspection of box-and-whiskers plots. Standardised

skewness and kurtosis values were nonsignificant at $z = \pm 2.58$ ($p < .01$). Normality was also confirmed via frequency histograms and normal quantile-quantile plots. Mauchly's test revealed that the assumption of sphericity was violated for the three-way interaction between valence, arousal and exposure duration, Mauchly's $W(2) = .83$, $p = .041$. The significance of this effect was unchanged, however, following a Greenhouse-Geisser correction. Uncorrected values have therefore been reported.

Catch Trials

On average, participants responded to 0.82% ($SD = 2.78$) of catch trials. The proportion of catch trial responses did not vary across the different cue types, $F < 1$.

Accuracy Data

Probe classification accuracy was high. The percentage of correct responses varied between 86% and 99% ($M = 94.76\%$, $SD = 3.28$). Due to the low frequency of errors, analysis of the accuracy data precluded meaningful results.

Reaction Time Data

Overall effects. Table 6.3 includes the mean RTs for the different cue types within each experimental condition. The RT data were analysed using a 2 × 2 × 2 × 3 repeated-measures ANCOVA, with valence (threatening vs. appetitive), arousal (low vs. high), validity (valid vs. invalid), and exposure duration (24 ms vs. 59 ms vs. 100 ms) as factors. Mean centered STAI-S and STAI-T scores were included as covariates and were nonsignificant, $F\text{s} \leq 2.71$, $p \geq .109$.

Table 6.3

Mean Response Times (ms), Standard Deviations (SD), and Cue Validity Indices (CVI) as a Function of Cue Type, Validity and Exposure Duration in Experiment 3.2.

		Exposure Condition								
		24 ms			59 ms			100 ms		
Cue Type	Cue Validity	*M*	*SD*	CVI	*M*	*SD*	CVI	*M*	*SD*	CVI
Low Arousing Threatening	Valid	536	53	9	519	51	37	503	50	82
	Invalid	545	51		555	67		585	60	
Low Arousing Appetitive	Valid	528	45	14	526	47	29	505	52	86
	Invalid	542	61		555	59		592	65	
High Arousing Threatening	Valid	535	40	7	532	50	32	519	50	67
	Invalid	543	58		564	72		586	75	
High Arousing Appetitive	Valid	531	40	18	528	47	31	529	59	70
	Invalid	549	68		560	63		599	61	
Neutral	Valid	537	49	15	528	44	42	501	49	84
	Invalid	553	50		570	48		585	46	

The results of the ANCOVA revealed a strong cue validity effect, with faster RTs on valid trials (M = 524 ms, SE = 6.43) than invalid trials (M = 565 ms, SE = 6.40), $F(1, 36) = 90.98$, $MSE = 4167.90$, $p < .001$, $\eta_p^2 = .72$. RTs were also influenced by the exposure duration of the cues, $F(2, 72) = 8.56$, $MSE = 1705.75$, $p < .001$, $\eta_p^2 = .19$, which was subsumed by a significant Validity × Exposure Duration interaction, $F(2, 72) = 39.48$, $MSE = 2124.70$, $p < .001$, $\eta_p^2 = .52$. With respect to cue type, a main effect of arousal was found, $F(1, 36) = 5.52$, $MSE = 1980.21$, $p = .024$, $\eta_p^2 = .13$. Reponses to the probes were slower following the presentation of high arousing pictures (M = 548 ms, SE = 6.35) compared to low arousing pictures (M = 541 ms, SE = 6.10). The main effect of valence was nonsignificant, $F < 1$. All interactions involving valence or arousal were nonsignificant, Fs ≤ 1.33, ps ≥ .270.

The interaction between cue validity and exposure duration is plotted in Figure 6.7. To decompose the combined effect of these variables, CVIs ($RT_{\text{Invalid Cue}} - RT_{\text{Valid Cue}}$) were calculated for each exposure condition, averaging over valence and arousal. After controlling for state and trait anxiety, the results of a one-way ANCOVA revealed that the CVIs varied as a function of exposure duration, $F(2, 72) = 39.48$, $MSE = 1062.35$, $p < .001$, $\eta_p^2 = .52$. The positive cue validity effect became stronger as the length of cue exposure increased. That is, CVIs obtained in the 100 ms exposure condition (M = 76, SE = 7.42) were larger than those calculated for the 59 ms exposure condition (M = 32, SE = 4.94), $F(1, 36) = 37.48$, $MSE = 1005.86$, $p < .001$, $\eta_p^2 = .51$, which in turn were larger than those obtained in the 24 ms exposure condition (M = 12, SE = 5.35), $F(1, 36) = 9.05$, $MSE = 876.15$, $p = .010$, $\eta_p^2 = .20$.

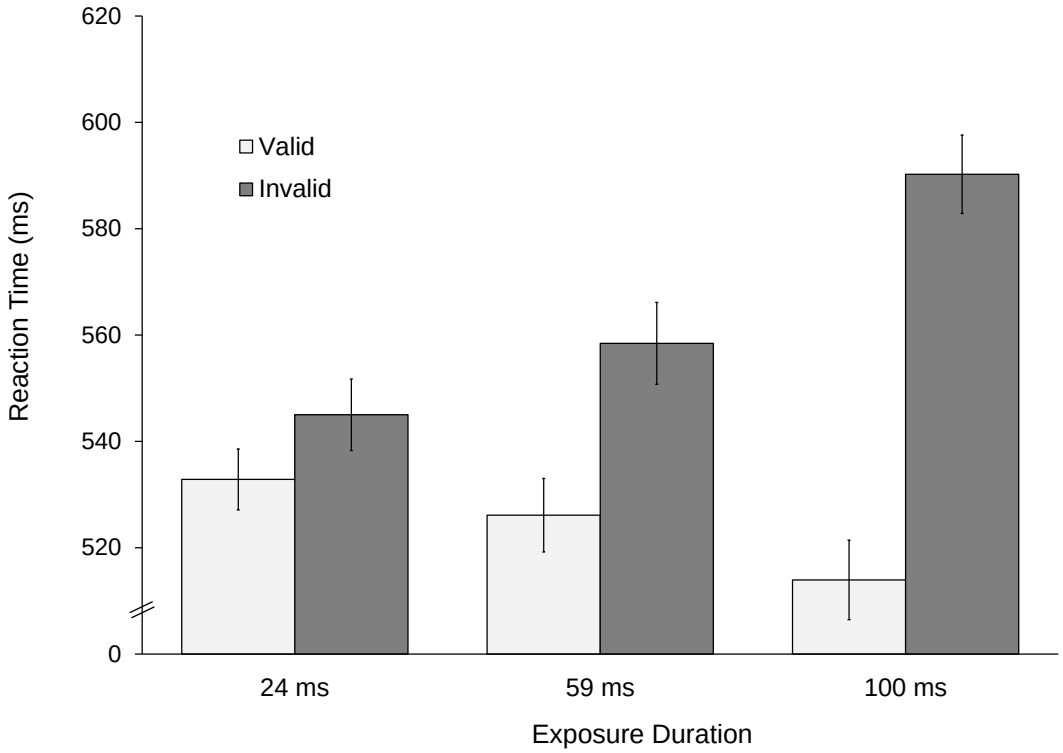

Figure 6.7. Mean reaction times as a function of cue validity and exposure duration (Experiment 3.2).

Discussion

As hypothesised, RTs were faster when the probes followed valid cues compared to invalid cues. Presumably, probe classifications were facilitated on valid trials because the cues had already directed attention to the probe's location. This result suggests that attention was generally oriented toward the cues. The size of the positive cue validity effect was large and greater than that observed in Experiment 3.1. Because the only modification made in the current experiment was to increase the proportion of valid trials to 75%, enhancement of the cue validity effect can be attributed to the predictive value of the cues. The predictive cues are assumed to have activated endogenous processes, which operated to maximise task efficiency by orienting and maintaining attention on the location where the probe would most

likely appear (Prinzmetal et al., 2005). Results also revealed that the effect of validity increased with the duration of cue exposure. This finding was not surprising given that under longer exposure conditions there was greater opportunity for endogenous processes to operate and amplify attention for the cues.

In agreement with Study 2, the current results indicated dissociable effects of motivationally significant stimuli on the consumption of processing resources versus the orienting of spatial attention. A main effect of arousal revealed that probe classification latencies were slowed following the presentation of high arousing pictures compared to low arousing pictures. This finding suggests that the high arousing pictures placed greater demands on processing resources, which were then unavailable for classifying the probe. In contrast to predictions that spatial attention would be influenced by the motivationally significant pictures, the effect of cue validity was not augmented on the basis of cue type. All interactions involving valence or arousal were nonsignificant, indicating an absence of facilitated engagement and delayed disengagement effects.

The absence of facilitated engagement was not unexpected. Given the high ratio of valid to invalid trials, cues were anticipated to attract attention regardless of their valence or arousal. With response speed already accelerated on valid trials due to the task-relevance of attending to the cues, any differences in RT between the cue types are likely to have been masked (cf. Koster, Verschuere et al., 2007; Mogg & Bradley, 1998). Consequently, this version of the SCT was insufficiently sensitive to detect facilitated engagement effects. The absence of delayed disengagement effects, however, was contrary to predictions. On invalid trials, which required disengagement from the cued location, spatial attention appeared to reorient to the probe without being affected by the affective qualities of the pictures. The absence of

differential disengagement effects for the motivationally significant pictures may be attributable to the brief duration of cue exposure. Although participants were assumed to attend to the cued location for the purpose of maximising task performance, there may have been insufficient time to process the affective qualities of the pictures before probe onset. In other words, it is likely that the brief exposure conditions limited perceptual processing of the pictures, allowing participants to take advantage of the probabilistic value of the cues without attentional disengagement being compromised by awareness of stimulus valence or arousal.

Cisler and Koster (2010) proposed that delayed disengagement occurs during strategic stages of processing, during which prefrontal cortical mechanisms regulate the allocation of attentional resources. Delayed disengagement from affective stimuli may therefore only occur when conditions are conducive to perceptual awareness of stimulus content. Supporting these claims, Koster, Verschuere et al. (2007) found that response latencies to invalidly cued probes were unaffected by masked faces displaying angry or happy expressions, despite reporting evidence of delayed disengagement from the same faces during an unmasked condition. These findings suggest that delayed disengagement may not occur when experimental conditions restrict perceptual processing of the cues. Although masking procedures were not employed in the current experiment, the brief duration of cue exposure ($\leq$ 100 ms) may not have afforded sufficient opportunity for the affective qualities of the pictures to influence attentional disengagement. To examine the possibility that delayed disengagement from motivationally significant stimuli may occur during later stages of processing, the exposure duration of the cues was increased in the subsequent experiment.

Experiment 3.3

In contrast to automatic attentional processes, endogenous allocation of attention is considered to operate along a slower time-course (Prinzmetal et al., 2009). Non-emotional cueing studies employing predictive cues have shown that endogenous attention is enhanced as the time between cue onset and the occurrence of the probe is increased (Posner, Cohen, & Rafal, 1982; Warner et al., 1990). If delayed disengagement is dependent on endogenous attention, as claimed by Cisler and Koster (2010), differences in the extent to which motivationally significant stimuli hold attention may be best observed under experimental conditions that capture later stages of processing (i.e., > 100 ms).

Delayed disengagement from threat has been reported in low anxious participants following 200 ms of cue exposure, with slower responses to invalidly cued probes following threatening pictures compared to neutral pictures (Sagliano, Trojano et al., 2014). Massar et al. (2011) reported similar results for nonselect participants, with slowed disengagement from fear conditioned stimuli that were presented for 200 ms prior to probe onset. Although these studies demonstrate that threatening stimuli may hold attention at 200 ms post-stimulus onset, Vogt et al. (2008) observed delayed disengagement from high arousing pictures at 150 ms, independent of valence. Spatial cueing studies employing appetitive stimuli have found that pictures of attractive members of the opposite sex hold attention longer compared to non-attractive faces following 500 ms of exposure (Koranyi & Rothermund, 2012; Maner, Gailliot, & DeWall, 2007; Maner, Gailliot, Rouby et al., 2007), raising the possibility that disengagement from threatening and appetitive stimuli may operate over distinct time-courses.

The current experiment was designed to detect differences in the rate of attentional disengagement from motivationally significant stimuli during later stages of information processing. The exposure duration of the cues was therefore increased, with pictures presented for 100 ms, 200 ms, and 400 ms prior to probe onset. Consistent with Experiment 3.2, the ratio of valid to invalid trials was 75:25, thereby promoting endogenous orienting to the cues. A positive cue validity effect was again predicted, qualified by a four-way interaction between valence, arousal, cue validity, and exposure duration. On the basis of the claim that stimulus arousal underlies delayed disengagement (Vogt et al., 2008), slower responding was predicted on invalid trials when the probes were preceded by high arousing cues compared to low arousing cues, indicating that participants took longer to shift their attention away from the location of the high arousing pictures. Competing predictions were formed on the assumption that delayed disengagement is specific to threatening stimuli. According to the threat-specific hypothesis, slower responses on invalid trials were expected following threatening cues compared to appetitive pictures, especially for the HAT pictures (Koster, Crombez et al., 2007). As informed by earlier studies (Massar et al., 2011; Sagliano, Trojano et al., 2014; Vogt et al., 2008), delayed disengagement effects were expected to be most prominent in the 200 ms exposure condition.

Method

Participants

Forty-four participants were sampled for Experiment 3.3. Two participants (4.55%) reported that they did not consider members of the opposite sex to be sexually appealing, and were therefore excluded from the final sample. The retained sample included 38 females (90.48%). Participants were aged from 18 to 56 years

(*M* = 22.29 years, *SD* = 7.11). STAI-S scores varied between 20 and 57 (*M* = 31.31, *SD* = 8.04), while STAI-T scores ranged from 23 to 67 (*M* = 37.60, *SD* = 9.77).

Materials & Procedure

The duration of cue exposure was modified for the SCT, such that the cues were presented for 100 ms, 200 ms, and 400 ms before probe onset. With this exception, all other task parameters and procedures were consistent with Experiment 3.2.

Results

Data Preparation

Two participants were found to have made an outlying proportion of incorrect responses on the SCT, equating to 24.30% and 16.70% of test trials. These cases were removed prior to analysis of the data. For the remaining participants, RTs for incorrect responses were discarded (2.79%). A third case was excluded due to slow responding (> 750 ms) on 45.17% of test trials. RTs briefer than 150 ms and slower than 750 ms were removed (10.98% of test trials), as were responses occurring outside of ± 2 *SD*s from a participant's mean RT for each experimental condition (0.77%). Analyses were conducted on 84.98% of the data obtained from the remaining 39 participants.

Statistical Assumptions

The RT data were free from univariate outliers, which were defined as standardised values exceeding $z = \pm 3.29$ ($p < .001$). Visual inspection of box-and-whiskers plots confirmed the absence of outliers. Standardised skewness and kurtosis values were nonsignificant at $z = \pm 2.58$ ($p < .01$) for all but one experimental condition. In the 200 ms exposure condition, RTs for invalidly cued probes preceded by HAA pictures were found to be negatively skewed ($z = -3.63$) and leptokurtic ($z =$

4.05). Frequency histograms and normal quantile-quantile plots confirmed normally distributed response latencies for all other experimental conditions. Additionally, the pattern of results remained unchanged following a logarithmic transformation of the RT data. To preserve interpretability, results obtained using untransformed RTs have been reported. Mauchly's test revealed that the assumption of sphericity was met for all main effects and interactions.

Catch Trials

One participant was found to have responded to 96% of catch trials and was therefore removed. No catch trial responses were made by any of the remaining participants ($N = 38$).

Accuracy Data

Participants achieved a high degree of task accuracy, with the percentage of correct responses ranging between 88% and 100% of test trials ($M = 96.69\%$, $SD = 2.58$). Because few errors were made on the task, analysis of the accuracy data was unwarranted.

Reaction Time Data

Overall effects. Mean RTs obtained for the different cue types within each experimental condition are reported in Table 6.4. These data were subjected to a 2 × 2 × 2 × 3 repeated-measures ANCOVA to determine the effects of valence (threatening vs. appetitive), arousal (low vs. high), validity (valid vs. invalid), and exposure duration (100 ms vs. 200 ms vs. 400 ms). Mean-centered STAI-S and STAI-T scores were entered as covariates, and were nonsignificant, Fs ≤ 1.71, ps $\geq .199$.

Table 6.4

Mean Response Times (ms), Standard Deviations (SD), and Cue Validity Indices (CVI) as a Function of Cue Type, Validity and Exposure Duration in Experiment 3.3.

		Exposure Condition								
		100 ms			200 ms			400 ms		
Cue Type	Cue Validity	*M*	*SD*	CVI	*M*	*SD*	CVI	*M*	*SD*	CVI
Low Arousing Threatening	Valid	552	62	38	523	62	73	532	56	67
	Invalid	590	64		595	60		599	43	
Low Arousing Appetitive	Valid	556	63	45	534	53	69	522	52	61
	Invalid	600	71		602	60		582	48	
High Arousing Threatening	Valid	567	48	42	535	57	69	537	69	67
	Invalid	609	53		604	50		604	60	
High Arousing Appetitive	Valid	566	55	47	539	54	67	532	62	80
	Invalid	614	67		607	75		612	47	
Neutral	Valid	557	50	42	522	55	84	522	52	71
	Invalid	598	55		607	46		593	41	

RTs were significantly affected by cue validity, with faster responding on valid trials (M = 541 ms, SE = 7.98) than invalid trials (M = 601 ms, SE = 5.18), F(1, 35) = 120.21, MSE = 6903.18, $p < .001$, $\eta_p^2 = .77$. A main effect of exposure duration was also found, F(2, 70) = 10.64, MSE = 2355.73, $p < .001$, $\eta_p^2 = .23$, which was qualified by a significant Validity × Exposure Duration interaction, F(2, 70) = 8.48, MSE = 1917.36, $p < .001$, $\eta_p^2 = .20$.

With respect to cue type, probe classification latencies were significantly affected by arousal, with slower responding to probes cued by high arousing pictures (M = 577 ms, SE = 6.13) than low arousing pictures (M = 566 ms, SE = 6.50), F(1, 35) = 14.94, MSE = 2020.11, $p < .001$, $\eta_p^2 = .30$. RTs were unaffected by the valence of the cues, $F < 1$. All interactions involving valence and arousal were nonsignificant, Fs ≤ 2.13, ps ≥ .126.

The combined effect of cue validity and exposure duration on RTs is plotted in Figure 6.8. As can be seen in the figure, a positive cue validity effect was observed in each exposure condition, with responses facilitated by valid cues and slowed by invalid cues. To follow-up the interaction, CVIs ($RT_{Invalid\ Cue} - RT_{Valid\ Cue}$) were calculated for each exposure condition, averaging over valence and arousal. After controlling scores obtained on the STAI, a one-way ANCOVA revealed that CVIs varied significantly across exposure conditions, F(2, 70) = 8.96, MSE = 958.68, $p < .001$, $\eta_p^2 = .20$. Cueing effects were larger in the 200 ms exposure condition (M = 69, SE = 8.14) compared to the 100 ms exposure condition (M = 43, SE = 4.88), F(1, 35) = 15.69, MSE = 847.87, $p < .001$, $\eta_p^2 = .31$. There was no difference in CVIs obtained in the 200 ms and 400 ms exposure conditions (M = 69, SE = 7.16), $F < 1$.

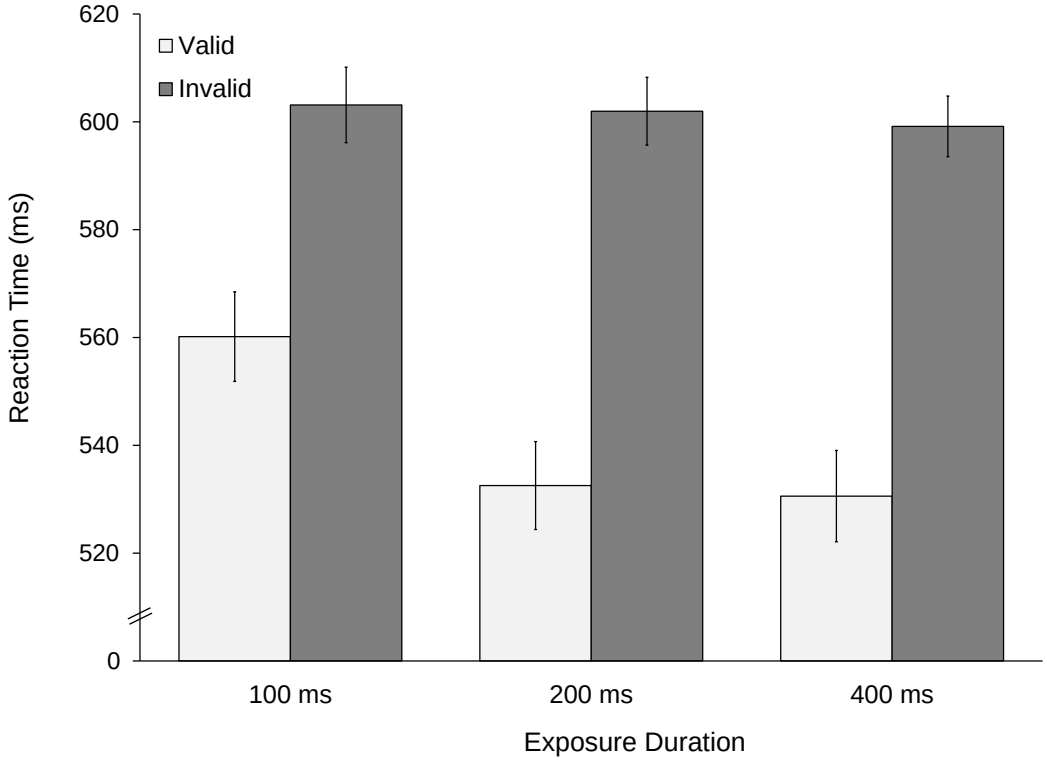

Figure 6.8. Mean reaction times as a function of cue validity and exposure duration (Experiment 3.3).

Discussion

Consistent with predictions, a positive cue validity effect confirmed that attention was directed towards the cues, thereby facilitating responses on valid trials and slowing responses on invalid trials. The interaction between validity and exposure duration revealed that the effect of cue validity was stronger following 200 ms of cue exposure compared to 100 ms, whereas cue validity indices in the 200 ms and 400 ms exposure conditions were comparable. These findings indicate that attention for the cues strengthened during the first 200 ms of cue exposure and was sustained until at least 400 ms post-stimulus onset.

The SCT employed in the current experiment was optimised for capturing attentional disengagement. The high proportion of valid trials was assumed to

motivate top-down attention for the cues, while the extended duration of cue exposure provided ample opportunity for endogenous processes to influence shifts of attention, which have been shown to initiate at around 150 ms to 300 ms (Busse, Katzner, & Treue, 2008; Theeuwes, 2010; Theeuwes, Atchley, & Kramer, 2000). Contrary to predictions, the cue validity effect was not augmented on the basis of valence, arousal or their interaction. As such, the time taken for participants to disengage their attention from the cues during invalid trials did not differ significantly across cue types. These data are in contrast with previous studies that have reported delayed disengagement from threatening and appetitive stimuli in low anxious and nonselect participants under similar exposure conditions (Koranyi & Rothermund, 2012; Maner, Gailliot, & DeWall, 2007; Maner, Gailliot, Rouby et al., 2007; Massar et al., 2011; Sagliano, Trojano et al., 2014; Vogt et al., 2008).

In the Sagliano, Trojano et al. (2014) study, low anxious participants were slower to respond to probes preceded by threatening relative to neutral pictures on valid *and* invalid trials at 200 ms post-stimulus onset. The interpretation offered for these results is that participants overtly avoided the threatening pictures by averting their gaze, thereby slowing responding on valid trials, while attention continued to be covertly directed towards the stimuli, resulting in delayed disengagement on invalid trials. Arguably, a simpler explanation is that the threatening pictures produced task-interference, which slowed RTs irrespective of where the probe appeared in relation to the cues. Furthermore, in studies that reported delayed disengagement from attractive, opposite-sex faces in nonselect participants, only RTs for invalid trials were analysed (Koranyi & Rothermund, 2012; Maner, Gailliot, & DeWall, 2007; Maner, Gailliot, Rouby et al., 2007). Consequently, it is unclear whether these

findings reflect delayed disengagement, as claimed by the authors, or task interference that slowed responding on both valid and invalid trials.

In the current experiment, the only effect concerning cue type was a main effect of arousal, with probe classification latencies slowed following the presentation of high arousing pictures compared to low arousing pictures. This effect was uninfluenced by the location of the cues relative to the probes and is therefore likely to reflect some form of task interference that is distinct from the allocation of spatial attention. Earlier studies have found that emotionally arousing stimuli can impair detection of non-affective targets (Arnell et al., 2007; Most et al., 2007; Müller et al., 2008), delay choice RTs (Ihssen & Keil, 2013), and interfere with controlled processes, such as naming font colours and solving math problems (Dresler et al., 2009; Schimmack, 2005). Importantly, the experimental tasks employed in these previous studies did not demand spatial shifts of attention. Considered together, stimulus arousal appears to affect non-spatial components of visual attention, such as perceptual processing speed or capacity, in addition to attentional disengagement, as observed in Study 2 (Experiments 2.1 & 2.2) and previous studies (Vogt et al., 2008). In the context of the motivational model of emotion (Lang et al., 1997, 1998), activation of the defensive and appetitive motivational systems may have interrupted ongoing information processing to enhance perceptual representations of the high arousing pictures, irrespective of cue validity. It is also possible that the high arousing stimuli prompted task-irrelevant processes related to their motivational significance or provocative content, which could have persisted despite attentional shifts towards another location (i.e., during invalid trials).

Chapter Summary

After changing the way participants responded to the probe and eliminating the spatial overlap between the cues and the probes, a robust cue validity effect was found in Study 3. Probe classification latencies were reliably faster on valid trials compared to invalid trials, demonstrating that attention was oriented towards the pictures at the time of probe onset. As suggested by Klein (2000), the absence of IoR in the current study can be ascribed to the higher degree of attention needed for classifying the probe as either a diamond or a square compared to the simpler probe localisation task employed in Study 2. Because inter-stimulus intervals between the cues and probes were brief, attention for the pictures is likely to have benefited from recruitment of attentional resources needed for performing the probe classification task, irrespective of the cues' predictive value.

When the cues were non-predictive of the probes (Experiment 3.1), and therefore irrelevant to the task, a combined effect of valence and arousal was found to influence the orienting of spatial attention at 24 ms post-stimulus onset. Pictures depicting human mutilations and blood injuries attracted speeded engagement, thereby facilitating faster responses to probes appearing in the same spatial location relative to other cue types. Saccadic eye movements are unlikely to have occurred during the brief period of cue exposure. Therefore facilitated engagement of the HAT cues can be confidently attributed to covert attentional processes, which, because of the equal ratio of valid to invalid trials, are considered to have been exogenously mediated.

Observations of facilitated engagement of HAT pictures challenges claims that biased engagement of threat is specific to anxious populations (Bar-Haim et al., 2007; Cisler & Koster, 2010; Massar et al., 2011; Sagliano, Trojano et al., 2014).

Rather, it appears that spatial attention orients more readily to HAT stimuli over and above individual differences in state and trait anxiety. Because this effect was observed during very early stages of processing that have rarely been examined in previous spatial cueing studies, the current findings suggest that facilitated engagement of highly threatening stimuli does occur in non-anxious individuals, but may operate earlier in comparison to those reporting higher levels of anxiety. In contrast to HAT cues, spatial attention for pictures depicting interpersonal aggression was comparable to that of the neutral pictures. This pattern of results is consistent with the cognitive-motivational model (Mogg & Bradley, 1998), which assumes that the threshold for evaluating threat severity is higher in non-anxious individuals. The LAT pictures employed in the current study may therefore have lacked sufficient arousal or threat intensity to facilitate attentional engagement in the nonselect sample.

Facilitated engagement of the HAT stimuli supports the notion of an evolved fear module (Öhman, 1996; Öhman & Mineka, 2001). As proposed by Öhman and Mineka (2001), preconscious engagement of biologically-prepared threats can optimise survival by facilitating rapid responding during potentially dangerous encounters. On the basis of neurological explanations of attention bias (Carlson et al., 2009; Davis & Whalen, 2001; LeDoux, 1996, 2000), fast, subcortical activation of the amygdala may underlie facilitated engagement of highly threatening stimuli, before they are subjected to higher-order appraisal processes mediated by the cortex.

On the basis of findings from non-affective spatial cueing studies that also employed a probe classification task (Prinzmetal et al., 2005; Prinzmetal et al., 2009), enhancing the predictive value of the cues was assumed to engage endogenous processes that increased allocation of attention to the cued location.

Although increasing the proportion of valid trials to 75% in Experiment 3.2 enhanced the positive cue validity effect, demonstrating heightened attention for the pictures, there was no evidence of delayed disengagement from any of the cue types. Even when the duration of cues exposure was extended to 100-400 ms (Experiment 3.3), disengagement of spatial attention was not affected by the affective qualities of the stimuli.

The absence of delayed disengagement effects could also be attributable to the nature of the task. Previous spatial cueing studies that have reported evidence of delayed disengagement in nonselect or non-anxious participants, including Study 2 of the current research (Experiments 2.1 & 2.2), have typically adopted a probe localisation task (Massar et al., 2011; Sagliano, Trojano et al., 2014; Vogt et al., 2008). Responding to the location of the probes has been shown to place fewer demands on attentional resources compared to probe classification tasks, such as that employed in the present study (Mogg & Bradley, 1999; Salemink et al., 2007). Under conditions that promote endogenous processes and volitional effort, attentional control mechanisms may facilitate flexible shifts of attention to optimise task performance (Klein, 2000). During invalid trials, this could have allowed attention to disengage the cued location and shift to the opposite periphery without being delayed by the affective content of the cues. Supporting this explanation, ERP studies have demonstrated that cortical responses to emotive facial expressions are attenuated when endogenous attention is consumed by contextual demands, such as during perceptual classification tasks similar to that employed in the current study (Eimer & Holmes, 2007; Eimer, Holmes, & McGlone, 2003).

Cortical activity has also shown to be sensitive to cue validity manipulations, with predictive cues activating frontoparietal regions implicated in attentional

control (Corbetta, Kincade, Ollinger, McAvoy, & Shulman, 2000; Corbetta & Shulman, 2002; Hopfinger, Buonocore, & Mangun, 2000; Scolari, Seidl-Rathkopf, & Kastner, 2015; Shulman et al., 2009; Vossel, Thiel, & Fink, 2006). When cues accurately predict the probe location on the majority of trials, violation of spatial expectancies elicits activation of the orbitofrontal cortex (Nobre, Coull, Frith, & Mesulam, 1999); a prefrontal brain region considered to underlie inhibition, in addition to playing an important role in the allocation of spatial attention to motivationally significant stimuli (Hartikainen, Ogawa, & Knight, 2012; Mohanty, Gitelman, Small, & Mesulam, 2008; Roberts & Wallis, 2000). In non-anxious individuals, enhanced activation of prefrontal structures, including the orbitofrontal cortex, may function to down-regulate subcortical limbic pathways, which could otherwise delay attentional disengagement (Cisler & Koster, 2010; Miller & Cohen, 2001). In Experiments 3.2 and 3.3, the demands of the probe classification task, combined with the high proportion of valid trials, is likely to have activated cortical structures involved in attentional control, thereby attenuating disproportionate allocation of spatial attention to emotional stimuli. This interpretation is consistent with the cognitive model (Mathews & Mackintosh, 1998), which claims that volitional effort can override biased attention to threatening stimuli for the purpose of preserving performance on concurrent tasks.

Whereas the orienting of spatial attention was unaffected by the content of the cues in Experiments 3.2 and 3.3, the main effect of stimulus arousal indicated that performance on the probe classification task was disrupted as a function of the cue's motivational significance, consistent with activation of the defensive and appetitive motivational systems (Lang et al., 1997, 1998). Because the effect of arousal was independent of exposure duration, it appears that the allocation of

resources to the high arousing pictures occurred early (i.e., 24 ms; Experiment 3.2) and was sustained for several hundred milliseconds (i.e., 400 ms; Experiment 3.3). Importantly, the effect of arousal also suggests that the motivationally significant stimuli diverted processing resources away from the probe classification task independently of spatial attention. Interpretation of the current data therefore implies a dissociation between spatial attention, including its constituent components (engagement, disengagement, and shifting), and non-spatial allocation of processing resources. Whereas attentional control processes mediated by the prefrontal cortex may attenuate the effects of valence and arousal on the disengagement of spatial attention, the effects of arousal on non-spatial components of attention, such as processing speed and capacity, appear to be more resistant to attentional control.

CHAPTER VII

GENERAL DISCUSSION

The present thesis examined whether the allocation of attention to motivationally significant stimuli was sensitive to stimulus valence or arousal in nonselect individuals after controlling for anxiety. The spatial cueing experiments described in Study 2 and 3 are the first to systematically examine the temporal characteristics of attention to threatening and appetitive pictures in nonselect participants, while also accounting for stimulus arousal.

In Chapter II, an overview of theoretical perspectives on attention to threatening stimuli was provided, including the information processing model (Beck & Clark, 1997; Clark & Beck, 2010), the two-stage model (Williams et al., 1988, 1997), the cognitive-motivational model (Mogg & Bradley, 1998), the cognitive model of selective processing (Mathews & Mackintosh, 1998), and the evolved fear module (Öhman, 1996; Öhman & Mineka, 2001). These models assume that threatening stimuli hold special significance and are prioritised by attention. Despite providing useful frameworks for examining how attention is allocated to negatively valenced material, threat-superiority models do not account for how attention is directed to pleasant stimuli. In contrast, the motivational model of emotion (Lang et al., 1997, 1998) predicts that attentional orienting is influenced by activation of defensive and appetitive motivational systems, which are responsive to innately aversive and pleasurable stimuli, respectively. Rather than valence, the motivational model assumes that stimulus arousal is the key determinant of attentional allocation. The contrasting assumptions of the threat-superiority models and the motivational model of emotion informed the hypotheses for each experiment in the current research.

Chapter III provided a review and critical evaluation of experimental paradigms that have been employed to investigate how attention is augmented by emotionally salient stimuli. Despite robust evidence that attention preferences emotionally-relevant material, including affective words, emotive facial expressions, and provocative pictures, the literature review revealed a number of methodological and interpretative limitations, which were summarised as follows: (i) a lack of consensus concerning the stimulus factors to which attention is sensitive due to infrequent inclusion of positively valenced stimuli and not accounting for stimulus arousal; (ii) the simultaneous presentation of neutral and affective stimuli in most experimental tasks precluded firm conclusions about whether emotional stimuli facilitate attentional engagement, delay disengagement, or both; (iii) comparatively few studies had systematically manipulated the duration of stimulus exposure to examine how attention is affected by emotional stimuli along the time-course of information processing; and (iv) limited investigation of how attention is allocated to emotional stimuli in nonselect participants.

To overcome the interpretative limitations of previous research, a novel set of motivationally significant and neutral picture stimuli was developed for the research reported in the present thesis. The pictures varied systematically in both valence and arousal, and were validated in Study 1 using verbal ratings and physiological indices of autonomic reactivity (see Chapter IV). Because the picture categories were matched on luminance, colour saturation, and picture complexity, results are unlikely to be due to low-level, perceptual confounds. Additionally, all of the pictures contained humans, including those representing neutral stimuli. Consequently, the current findings cannot be attributed to the presence of people in the motivationally significant pictures.

Across a series of experiments, the pictures served as cues in a SCT designed to examine the effects of valence and arousal on the specific components of spatial attention. The speed of attentional engagement was indexed by response latencies on valid trials, when the probe appeared in the same location as the preceding picture. The time taken to disengage attention was indexed by response latencies on invalid trials, when the probe and picture appeared in opposite locations. An advantage of using the SCT is that the exposure duration of the stimuli could be systematically varied, allowing examination of the time-course of attention to the affective pictures. In Study 2, the SCT required participants to respond to the probe's location following the offset of the pictures (see Chapter V). Study 3 employed a more demanding probe classification task and the spatial configuration of the cues relative to the probes was modified to minimise perceptual competition (see Chapter VI). In addition to varying the exposure duration of the cues, the ratio of valid to invalid cues was also varied across experiments in order to manipulate the influence of top-down, endogenous processes. Because the research was designed to determine the extent to which attention is influenced by affectively valenced stimuli in the general population, all experiments were conducted using nonselect participants, and state and trait anxiety were statistically controlled.

Response latencies on the SCT were subjected to repeated-measures ANCOVAs to determine the effects of cue valence and arousal on attention. Detailed interpretations were provided in the Discussion sections for each study, and results were reconciled with previous literature and theory, including threat-superiority models (Beck & Clark, 1997; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Öhman, 1996; Öhman & Mineka, 2001; Williams et al., 1988, 1997) and the motivational model of emotion (Lang et al., 1997, 1998). The principal findings

from the current research suggest that valence and arousal affect spatial and non-spatial aspects of visual attention during the first 1000 ms of stimulus processing, including: (i) rapid engagement of high arousing stimuli that are symbolic of potential threats and danger; (ii) delayed disengagement from high arousing stimuli, in addition to less arousing, threatening stimuli; and (iii) perceptual interference associated with stimulus arousal that is independent of the orienting of spatial attention. These effects were moderated by the spatial arrangement of the stimuli, exposure duration, and contextual demands.

Threat-Superiority Hypothesis

The results of the thesis partially support the assumption that spatial attention is preferentially allocated to threatening stimuli (Beck & Clark, 1997; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Öhman, 1996; Öhman & Mineka, 2001). Rather than being attributable to the individual effect of valence, however, the allocation of attention to threatening stimuli appears to be moderated by stimulus arousal.

Facilitated Engagement

Across six experiments, facilitated engagement was only observed for pictures depicting blood injuries and mutilations, indicating that spatial attention preferentially engages threatening stimuli that are sufficiently arousing. Given that the degree of arousal elicited by a stimulus is presumed to correspond to its motivational significance (Bradley & Lang, 2007; Lang et al., 1997, 1998), the current findings indicate that attentional engagement is facilitated for stimuli that are both threatening and highly relevant to survival. Several of the models described in Chapter II propose that a threat intensity threshold determines whether attention is directed towards negatively valenced stimuli (Mathews & Mackintosh, 1998; Mogg

& Bradley, 1998; Williams et al., 1988, 1997). The cognitive-motivational model, for example, assumes that attention is allocated to threatening stimuli according to the reactivity of a VES (Mogg & Bradley, 1998). Similarly, the two-stage model proposes that an ADM appraises stimuli on the basis of threat value (Williams et al., 1988, 1997). In light of the current findings, the threshold for determining threat severity appears to be sensitive to stimulus arousal. Whereas negative valence signals that a stimulus is potentially dangerous or threatening, arousal likely conveys the severity of the threat. The absence of facilitated engagement effects for the LAT cues is in line with this interpretation. Presumably, the pictures depicting interpersonal aggression were not sufficiently arousing to exceed the threshold for facilitating attentional engagement in nonselect participants. This explanation also aligns with theories that non-anxious individuals have a higher threshold for attending to threatening stimuli compared to their more anxious counterparts (Mogg & Bradley, 1998; Mogg et al., 2004; Wilson & MacLeod, 2003).

Facilitated engagement of pictures depicting mutilated bodies and blood injuries was observed at 24 ms post-stimulus onset, but only when the cues did not predict the location of the probes above chance (Experiment 3.1). Because the pictures were irrelevant to the task, facilitated engagement of the HAT stimuli was considered to have occurred exogenously (Chica et al., 2014; Jonides, 1981; Lupiáñez et al., 2004). This finding is consistent with predictions of the evolved fear module, which proposes that stimuli are pre-attentively analysed for the presence of features that are reflective of evolutionary threats (Öhman, 1996; Öhman & Mineka, 2001). Upon receiving input from the feature detectors that a potential threat is present, the arousal system can prompt attentional orienting prior to conscious awareness of the stimulus. From a survival standpoint, blood injuries and mutilated

bodies signal that a threat to physical wellbeing is present in the environment and contain features (blood, open wounds, body disfigurement, etc.) that have likely gained significance through evolutionary contingencies. Given that the cues were only presented for 24 ms when facilitated engagement was observed, it appears that detailed processing is unnecessary for spatial attention to orient to highly threatening stimuli, consistent with the assumption that neurocognitive responses to biologically-prepared threat stimuli operate pre-attentively and in the absence of conscious awareness (Öhman & Mineka, 2001). Under longer exposure conditions, facilitated engagement of the HAT pictures was absent. Therefore, although attention may orient rapidly to HAT stimuli, this effect appears to be isolated to very early stages of processing in nonselect individuals.

In addition to the duration of the cues and their relevance to contextual demands, another critical factor in determining the allocation of attention to the HAT stimuli concerned the nature of the task. Rapid engagement of the HAT pictures was only observed when the SCT required participants to discriminate between two perceptually similar probes (Study 3). In contrast, when participants were required to respond to the location of the probes, spatial attention appeared to orient away from the HAT pictures (Study 2). These discordant findings indicate that facilitation effects may be restricted to more demanding classification tasks, perhaps due to the delayed onset of IoR (Chica et al., 2014; Lupiáñez et al., 1997). Another important consideration concerns the spatial configuration of the probes relative to the cues. Regardless of cue type, responses in Study 2 were generally delayed when the probes overlapped with the cues on valid trials. This result was surprising given that previous studies have reported facilitated attentional engagement of affective stimuli (Koster, Crombez, Van Damme et al., 2004; Koster, Crombez et al., 2005; Koster,

Crombez et al., 2007; Massar et al., 2011; Sawada & Sato, 2015). A plausible explanation for the discordant results in Study 2 is that perceptual competition masked facilitated engagement of the affective pictures.

Delayed Disengagement

When participants responded to the location of the probes (Study 2), enhanced attentional orienting was observed towards the less arousing, threatening pictures. This occurred when the cues were exposed between 100 ms and 1000 ms and rendered task-relevant by increasing the proportion of valid trials to 75% (Experiment 2.2). On trials that required participants to shift attention away from the cued location before responding to the probe (i.e., invalid trials), spatial attention was slower to disengage from pictures depicting interpersonal aggression and attack scenes compared to the neutral pictures. Disengagement from the LAT pictures was also delayed during early stages of processing (24-100 ms), when the cues were non-predictive of the probe's location, and therefore irrelevant to the task (Experiment 2.3). In contrast to pictures of blood injuries and mutilations, the degree of threat posed by the LAT stimuli may have been more ambiguous, necessitating longer processing (Purkis et al., 2009; Whalen, 1998). It is plausible that when the degree of threat posed by a stimulus is not immediately clear, elaborative processes may facilitate additional information gathering so that adaptive responses can be determined. This interpretation is consistent with the information processing model (Beck & Clark, 1997; Clark & Beck, 2010), which proposes that a threat elaboration mechanism operates to maintain attention on potentially threatening stimuli, while they are subjected to top-down, evaluative processes.

There was no evidence of delayed disengagement from the threatening pictures when a probe classification task was employed in Study 3. As indicated by

slower overall RTs and reduced accuracy, the probe classification placed greater demands on attentional resources than the localisation task used in Study 2. The absence of delayed disengagement can therefore be attributed to the increased effort needed to classify the probes, which suppressed the influence of the threatening pictures on spatial attention during strategic stages of processing. This interpretation aligns with the cognitive model of selective processing (Mathews & Mackintosh, 1998), which proposes that attention to threatening stimuli can be inhibited by top-down, volitional processes that are responsive to contextual demands.

Attentional Avoidance

In Study 2, it appeared that attention was slower to reorient to spatial locations cued by pictures of blood injuries and mutilations compared to neutral and less arousing threatening pictures, implying that IoR from threatening stimuli was potentiated on the basis of stimulus arousal (Experiments 2.1, 2.2, & 2.3). Following rapid engagement, avoidance may motivate attention away from HAT stimuli to reduce aversive reactions (Ellenbogen et al., 2002; Ellenbogen et al., 2006) and preserve task performance (Mathews & Mackintosh, 1998). Challenging this interpretation, however, negative engagement indices were recorded for the HAT pictures even under brief exposure conditions (i.e., $\leq$ 100 ms; Experiment 2.3). Assuming that attentional avoidance is a strategic process (Cisler & Koster, 2010; Derryberry & Reed, 2002), it is unlikely there was sufficient opportunity for attention to avoid the HAT pictures by 100 ms post-stimulus onset. Because the cues spatially overlapped with the probes on valid trials in Study 2, the negative engagement indices obtained by the HAT pictures might be better explained by emotion-induced blindness, as opposed to avoidance.

Non-Spatial Aspects of Visual Attention

When interpreting the delayed responses on valid trials in Study 2, it is important to draw a distinction between processes that affect conscious perception from those related to the orienting of spatial attention. Emotion-induced blindness is considered to reflect competition between perceptual representations of emotional and non-emotional stimuli early in the stream of visual information processing (Kennedy & Most, 2012; Most & Wang, 2011; Wang et al., 2012). According to this explanation, representations of the HAT pictures in the visual cortex may have disrupted processes involved in perception of the probes, thereby delaying responses. Importantly, this may have occurred in spite of spatial attention being directed *towards* the HAT pictures. When the spatial overlap between the cues and the probes was eliminated in Study 3, engagement indices were either elevated for the HAT pictures (Experiment 3.1) or unaffected by cue type (Experiments 3.2 & 3.3). This suggests that perceptual representations of HAT stimuli may impair detection of a target stimulus, such as an attentional probe, but only when the stimuli spatially overlap and occur within close temporal proximity.

During early stages of processing, the threatening pictures were found to produce a general slowing effect that was independent of the probe's location (≤ 100 ms; Experiment 2.3). This finding converges with findings from ERP studies and demonstrates that evaluation of stimulus valence occurs early in the stream of information processing (Smith et al., 2003). In the context of the motivational model of emotion (Lang et al., 1997, 1998), rapid evaluation of valence may prime activation of either the defensive or appetitive motivational system before the degree of activation is determined by stimulus arousal. It is important to note, however, that a main effect of valence was not observed in Study 3, when a probe classification

task was employed. Assuming that volitional effort directed more attentional resources towards classifying the probes, there would have been fewer resources for processing stimulus valence. This suggests that early evaluation of stimulus valence can be overridden in the context of demanding tasks. In contrast, facilitated engagement is assumed to be an automatic process that is uninfluenced by the availability of cognitive resources (Carlson & Reinke, 2008; Cisler et al., 2009; Cisler & Koster, 2010; Koster, Crombez et al., 2007), which accounts for why attention oriented more readily to the HAT pictures in spite of increased task demands (Experiment 3.1).

Arousal Hypothesis

In support of the arousal hypothesis, indices of physiological orienting, including decelerated HR and increased skin conductance, were elevated following the presentation of the high arousing pictures (Study 1). Even after controlling for subjective interest, physiological indices of the OR were better predicted by ratings of arousal than valence. Findings from the SCT also provided support for the arousal hypothesis, with RT data indicating that both spatial and non-spatial aspects of visual attention were influenced by stimulus arousal.

Facilitated Engagement

As noted, facilitated engagement of threatening stimuli was moderated by stimulus arousal at 24 ms post-stimulus onset (Experiment 3.1). There was no evidence that engagement was facilitated for the erotic pictures, despite these stimuli being rated as equally arousing as the HAT pictures. In Study 2, negative engagement indices suggested that attention oriented *away* from the high arousing pictures relative to the neutral pictures (Experiments 2.1 & 2.2). As discussed below,

however, these findings are likely to reflect perceptual competition between the cues and the probes on valid trials, rather than the orienting of spatial attention, *per se*.

Delayed Disengagement

In agreement with previous findings (Sawada & Sato, 2015; Vogt et al., 2008), response latencies on invalid trials indicated that attentional disengagement was delayed from the high arousing pictures at 400 ms post-stimulus onset, but only when participants were required to indicate the location of the probes (Experiment 2.1). These data lend support to the motivational model of emotion (Lang et al., 1997, 1998) by demonstrating that high arousing stimuli can attract preferential attention, irrespective of valence, when contextual demands are low. From this perspective, the degree to which motivational systems (defensive or appetitive) are activated determines the extent to which a stimulus maintains attention. Slowed disengagement could enable enhanced processing to evaluate the relevance of a stimulus to the motivational needs of the individual and consideration of adaptive responses. This interpretation is supported by findings that the amygdala is responsive to stimulus arousal (Garavan et al., 2001; Kensinger & Schacter, 2006; Lewis et al., 2007) and may function as a relevance detector (Sander et al., 2003).

When task demands were increased in Study 3, there was no significant effect of arousal on attentional disengagement. Flexible shifting of attention from one spatial location to another is regarded as an attentional control mechanism, which can be enhanced by increased effort in non-anxious individuals (Corbetta & Shulman, 2002; Derryberry & Reed, 2002; Yantis et al., 2002). Delayed disengagement from motivationally significant stimuli may therefore be limited to relatively simple tasks that place minimal demands on attentional capacity, such as the probe localisation task employed in Study 2. Under conditions that place greater

demands on attentional resources, activation of prefrontal cortical structures may accelerate the redeployment of spatial attention in the service of optimising task performance. In Study 3, the need to process the probes so that they could be accurately classified is likely to have superseded the motivational significance of the pictures, thereby allowing attention to shift flexibly to the probes during invalid trials.

Attentional Avoidance

The high arousing pictures were found to elicit a reverse cue validity effect in Study 2, suggesting that attention oriented away from the stimuli as a function of arousal (Experiments 2.1 & 2.2). Additionally, the high arousing pictures slowed responses to probes appearing in the same location (i.e., valid trials), which was reflected by negative engagement indices. Although similar results have previously been interpreted in terms of attentional avoidance (Koster, Crombez, Verschuere, Van Damme et al., 2006; Koster, Crombez et al., 2007; Sagliano, Trojano et al., 2014), there was no evidence that attention was slower to engage the high arousing pictures when the spatial overlap between the cues and the probe was eliminated in Study 3. These discordant results indicate that the high arousing pictures affected perceptual processes rather than precipitating attentional avoidance.

Non-Spatial Aspects of Visual Attention

The negative engagement indices obtained by the high arousing pictures in Study 2 can be accounted for by arousal-biased competition that resulted from the overlapping configuration of the cues and probes (Mather & Sutherland, 2011). According to this explanation, stimulus arousal biases perception in favour of motivationally significant stimuli, but at the expense of less salient stimuli that occur within close spatiotemporal proximity (i.e., the probes). If the degree of arousal

elicited by a stimulus is high, detection of target stimuli appearing within the same spatial vicinity is impaired. In contrast, less arousing stimuli assert weaker influence on perceptual competition, facilitating comparatively faster detection of other stimuli appearing in the same location.

Further highlighting the influence of stimulus arousal on visual information processing, overall response latencies were slowed for probes that followed high arousing pictures (Experiments 2.1, 2.2, & 3.3). The cost of arousal on response speed increased during the first 400 ms post-stimulus onset, and, albeit weaker, was still observable at 1000 ms (Experiment 2.2). Given the enduring nature of this effect, and the fact that arousal slowed responding independently of the location of the probes relative to the cues, it appears that non-spatial aspects of visual attention are affected by stimulus arousal, such as the capacity or speed of information processing. High arousing stimuli may initiate task-irrelevant processing related to their evocative content, and in doing so divert attentional resources away from locating and responding to task-focal information. Arousal-driven interference could also reflect an innate defence mechanism that momentarily freezes current activity (Algom et al., 2004; Estes & Verges, 2008; Fox et al., 2001). Rather than occurring exclusively in the presence of threatening stimuli, however, the current results indicate that freezing reactions are also elicited by high arousing, appetitive stimuli. Freezing likely serves an adaptive function by enhancing perception of motivationally significant stimuli and preparing the body for action (Bradley, Codispoti, Cuthbert et al., 2001; Lojowska, Gladwin, Hermans, & Roelofs, 2015; Mouras, Lelard, Ahmaidi, Godefroy, & Krystkowiak, 2015). Interpreting the effect of arousal in terms of freezing is supported by observations of sustained cardiac deceleration following the presentation of both HAT and HAA pictures (Study 1),

which was considered to reflect increased sensory intake of the stimuli (Graham, 1979, 1992).

Integrated Model of Attention to Motivationally Significant Stimuli

A tentative model that attempts to account for the present results in the context of previous findings and theory is proposed. As can be seen in Figure 7.1, the model includes several components suggested by earlier frameworks in order to explain the interrelationships between stimulus valence and arousal on spatial attention, in addition to non-spatial aspects of visual information processing.

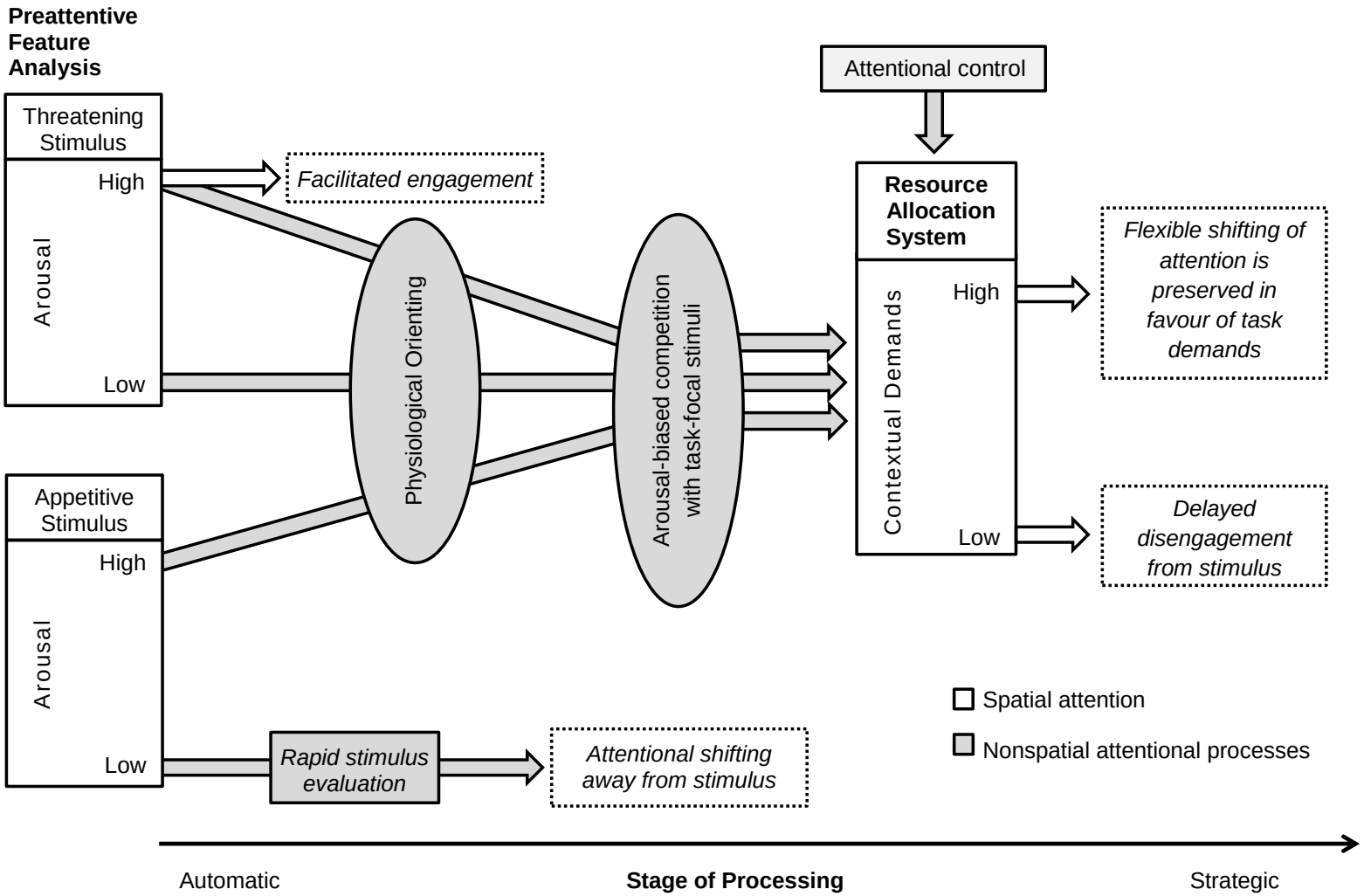

Figure 7.1. Proposed integrated model of attention to motivationally significant stimuli.

Consistent with the motivational model of emotion (Lang et al., 1997, 1998) and the evolved fear module (Öhman, 1996; Öhman & Mineka, 2001), it is assumed that affective stimuli are preattentively analysed on the basis of their features, including automatic, but coarse, appraisal of stimulus valence and arousal. Activation of the defensive or appetitive motivational system occurs when the features of a stimulus match representations of innately threatening or appetitive stimuli stored in memory (Bradley et al., 2012). On the basis of stimulus arousal, the autonomic nervous system mediates physiological reactions that facilitate attentional orienting to motivationally significant stimuli and prime adaptive motor responses. As observed in Study 1, this includes increased skin conductance and decelerated HR. Importantly, it appears that physiological orienting operates according to stimulus arousal, regardless of valence.

In agreement with LeDoux's (1996) dual pathway theory of threat processing, the proposed model assumes that subcortical projections from the thalamus to the amygdala facilitate rapid engagement of HAT stimuli during very early stages of processing, as observed in Experiment 3.1. Converging with threat-superiority models (Beck & Clark, 1997; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Öhman, 1996; Öhman & Mineka, 2001), the integrated model predicts that facilitated engagement is specific to threatening stimuli that are sufficiently intense or arousing. This assumption aligns with the results of Experiment 3.1, in addition to fMRI findings which have revealed that activation of the amygdala in response to negative stimuli is moderated by stimulus arousal (Garavan et al., 2001).

When activated by emotionally arousing stimuli, projections from the amygdala to the visual cortex are predicted to bias perceptual competition by

enhancing representations of motivationally significant stimuli (Vuilleumier, 2005). As found in Study 2, perception is assumed to preference high arousing stimuli at the expense of less salient stimuli appearing within close spatiotemporal proximity (Desimone, 1998; Mather & Sutherland, 2011). It is assumed here that arousal-biased competition operates to accelerate stimulus identification prior to the allocation of endogenous attention. Perceptual competition may also coincide with a cognitive freezing response that enhances sensory intake of motivationally significant stimuli, while readying adaptive motor responses (Bradley, Codispoti, Cuthbert et al., 2001; Lojowska et al., 2015; Mouras et al., 2015).

The integrated model proposes that output from the visual cortex feeds into a *resource allocation system* that is mediated by frontoparietal brain regions (Corbetta & Shulman, 2002; Hartikainen et al., 2012; Mohanty et al., 2008; Scolari et al., 2015). Not unlike the GES proposed by Mogg and Bradley (1998), the resource allocation system determines the deployment of endogenous attention to motivationally significant stimuli while remaining sensitive to contextual demands. If contextual demands are low, high arousing stimuli are predicted to hold attention for longer, thereby enabling enhanced stimulus processing to determine the relevance of the stimulus to current motivational priorities and the need for immediate action. In contrast, if current tasks are more demanding of attentional resources, top-down signals originating from higher-order cortical regions are assumed to override the influence of stimulus arousal on attentional disengagement, thus allowing attention to shift flexibly from a motivationally significant stimulus toward task-focal stimuli. These predictions are supported by studies that have found reduced attention for affective stimuli under conditions of high cognitive load (Berggren, Richards, Taylor, & Derakshan, 2013; Erthal et al., 2005; Van Dillen,

Heslenfeld, & Koole, 2009). Consistent with the effortful task demand module proposed by Mathews and Mackintosh (1998), increased task demands are assumed to motivate volitional effort, which enhances top-down, attentional control. If the motivation to maximise task efficiency outweighs the motivational relevance of concurrently occurring stimuli, the effects of stimulus arousal on attention may be inhibited during strategic stages of processing.

In addition to accounting for the influence of top-down attentional control on the allocation of attention, the integrated model also explains the differential effect of stimulus arousal on the processing speed of negative and positive stimuli (Feng et al., 2012; Purkis et al., 2009). Whereas high arousal facilitates faster engagement of threatening stimuli, low to moderate arousal is more likely to delay disengagement so that the severity of the threat can be evaluated. Similarly, appetitive stimuli that elicit high levels of arousal may also necessitate longer processing time to determine whether they should be approached and pursued. Because the consequences of not responding to appetitive stimuli are likely to be less severe than those of not responding to severely threatening stimuli, additional time can be taken to weigh the motivational relevance of highly arousing, appetitive stimuli against contextual demands without compromising survival. In contrast, less arousing, appetitive stimuli may not prompt sufficient physiological orienting to enhance their perceptual representation in the visual cortex. Moreover, as suggested by the results of Experiment 2.3, in addition to previous studies (Eder & Rothermund, 2010; Feng et al., 2012; Purkis et al., 2009; Robinson et al., 2004), LAA stimuli could be evaluated and dismissed comparatively early in the stream of information processing, allowing attention to shift towards other spatial locations unencumbered. Supporting this

conclusion, there was no evidence of delayed disengagement from the LAA stimuli in any of the spatial cueing experiments.

Limitations and Directions for Future Research

Despite the methodological strengths of the current thesis, there are several limitations that are important to recognise prior to drawing firm conclusions from the findings and which may guide future research. Firstly, interpretations concerning the allocation of spatial attention to the high arousing pictures in Study 2 were complicated by a general slowing effect. Consequently, it cannot be entirely ruled out that spatial effects were influenced by arousal-driven interference. On valid trials, interference could have masked facilitated engagement of the high arousing stimuli. Similarly, on invalid trials, estimates of delayed disengagement may have been inflated for the high arousing pictures, thereby appearing larger than they would in the absence of interference. In Study 3, however, general response slowing was observed following the high arousing pictures in the absence of delayed disengagement. It therefore appears that arousal-driven interference is dissociable from delayed disengagement, supporting conclusions that stimulus arousal influences both spatial and non-spatial aspects of visual attention, depending on contextual demands. Further research is needed, however, to disentangle the effects of arousal on spatial attention from arousal-driven response slowing. To this end, tasks that substitute RT with perceptual accuracy measurements may help to isolate the effects of stimulus arousal on early attentional processes from more general response slowing (Van Damme, Crombez, & Notebaert, 2008).

To minimise the influence of eye movements on the spatial cueing data, participants were explicitly instructed not to move their eyes during the SCT and to focus their gaze on a central fixation cross. As eye movements were not monitored,

however, it cannot be ruled out that overt shifts of attention occurred and influenced the data. Although this may compromise the confidence with which the data can be attributed to covert attentional processes, it is important to recognise that eye movements typically occur *after* covert shifts of attention (Hoffman, 1998; Peterson, Kramer, & Irwin, 2004). It is therefore unlikely that the conclusions drawn from the data would have been any different had eye movements been controlled.

Though the samples were nonselect, convenience sampling resulted in a disproportionate number of female participants. Neurophysiological studies have found that threatening and high arousing pictures evoke greater physiological reactions and larger ERP amplitudes in females than males (Bradley, Codispoti, Sabatinelli, & Lang, 2001; Lithari et al., 2010). These findings raise the possibility that the effects of valence and arousal on attention could have varied as a function of sex. To examine whether the results were comparable for male and female participants, data from the SCT were reanalysed with gender included as a between-subjects factor. None of the higher-order interactions involving valence and arousal reported in Study 2 and 3 were found to vary as a function of gender, Fs ≤ 2.06, ps $\geq .160$. Therefore, the results of the thesis are likely to be generalisable across sexes.

Finally, additional studies are needed to replicate the current results using different exemplars of threatening and appetitive stimuli. Of particular note, there was no evidence that attentional engagement was facilitated for the erotic pictures, despite these stimuli being matched with the HAT pictures in terms of arousal. Although erotic pictures were chosen to represent HAA stimuli due to their resistance to satiation (Bradley, Codispoti, Cuthbert et al., 2001), their motivational significance is likely to vary between individuals, especially amongst female participants (Bradley, Codispoti, Sabatinelli et al., 2001). It is important to recall,

however, that picture ratings obtained from each sample in the present thesis reliably demonstrated that the erotic pictures were perceived as both pleasurable and high arousing relative to the neutral pictures. Moreover, the physiological data from Study 1 indicated that the HAA pictures also elicited comparatively greater autonomic arousal, thereby attesting to the appetitive significance of the erotic pictures in the predominantly female samples employed here. That being said, future studies may wish to consider how attention prioritises other types of appetitive stimuli, while also accounting for valence and arousal. Furthermore, while it is assumed that the effects of valence and arousal observed in the current research were driven by biological imperatives and reflect the influence of evolution on our neurocognitive systems, the picture set employed did not include ontogenetic stimuli, which may also vary in both valence and arousal. Pictures depicting firearms, for example, have been shown to attract preferential attention (Blanchette, 2006; Fox, Griggs, & Mouchlianitis, 2007), as have stimuli associated with monetary rewards (Rutherford, O'Brien, & Raymond, 2010; Theeuwes & Belopolsky, 2012). Such findings demonstrate that learned associations can also influence the allocation of attention. In order to draw firm conclusions about the influence of biological-preparedness on attention for affective stimuli, it is recommended that future studies compare attention for phylogenetic and ontogenetic stimuli that are matched on arousal.

Summary and Conclusions

A large body of research has sought to clarify the effects of emotional stimuli on attention. While the majority of previous studies have focused on attention to threatening stimuli, the present thesis demonstrated that spatial and non-spatial aspects of visual attention are influenced by stimulus arousal, in addition to valence. After establishing a novel set of motivationally significant pictures that varied in

affective valence and arousal, these stimuli were included in a series of spatial cueing experiments designed to examine the distinct components of spatial attention. Results indicated that (i) facilitated engagement of threatening stimuli is moderated by arousal during very early stages of information processing; (ii) attention is slower to disengage from high arousing stimuli, in addition to less arousing, threatening stimuli, when contextual demands are low; (iii) high arousing stimuli can bias perceptual competition at the expense of task-focal stimuli appearing within close spatiotemporal proximity; and (iv) stimulus arousal also exerts a more general slowing effect that can interfere with concurrent tasks. These findings occurred independently of state and trait anxiety and are considered to reflect how attention is allocated to motivationally significant stimuli in individuals from the general population.

On the basis of the data reported here, a tentative model was proposed to explain the individual and interactive effects of valence and arousal on visual attention. In agreement with the notion of a threat-superiority bias, the integrative model assumes that spatial attention rapidly engages threatening stimuli that are highly relevant to survival. Although early attentional processes preference sufficiently arousing, threat stimuli, strategic stages of processing are assumed to be predominantly affected by stimulus arousal. Prior to the allocation of endogenous attention, arousal-biased competition facilitates identification of motivationally significant stimuli, irrespective of valence. This information is forwarded to a resource allocation system, which determines the deployment of attention during strategic stages of processing. The model predicts that high arousing stimuli will maintain attention while their relevance to current motivational needs is evaluated and the need for action is determined. Similarly, less arousing, threatening stimuli

may also delay attentional disengagement so that the severity of the threat can be assessed. Importantly, contextual demands determine whether or not a stimulus maintains attention. Because delayed disengagement was observed when task demands were low, but was absent when demands were increased, it appears that the effect of arousal on the redeployment of attention can be attenuated by top-down, attentional control. Although the proposed model is tentative, it may provide a useful framework for future research examining the effects of stimulus valence and arousal on visual attention. Importantly, additional studies are needed to replicate the current results using different exemplars of threatening and appetitive stimuli.

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Appendix A

Explanatory Statement

School of Psychology

Project Title: Attention toward motivationally significant stimuli

Project Number: **RO1607**

Information for Participants in the Psychology Cognition Laboratories

The research carried out in the Psychology Cognition Laboratories includes a number of new and continuing research projects. Our studies are concerned with understanding more about the nature of emotion and cognitive processes. The success of our research is vitally dependent upon the assistance of volunteers like yourself, and we are extremely grateful for your participation.

Participation in this research includes completing some questionnaires and performing computer-administered tasks that will involve the presentation of photographs which vary in emotional tone and arousal. Please be aware that some of these images may include graphic content depicting violence, human injury, and erotica.

The study will take about 75 minutes to complete. Any data that you provide is anonymous, so please do not write your name on any of the questionnaires. This data will be stored at the university for 5 years. You are free to withdraw from the experiment at any time without prejudice.

This study has been approved by the Bond University Human Research Ethics Committee (BUHREC) in accordance with the National Health and Medical Research Council's guidelines. If you would like to discuss your participation in the study, or be informed of the aggregate research findings, please contact the principal investigator, Dr. Mark Edwards on 5595 2673. If you have any complaints concerning the manner in which the research is conducted, please do not hesitate to contact BUHREC quoting the above project number. BUHREC can be contacted on:

Bond University Human Research Ethics Committee
C/O Office of Research Services
Bond University, Gold Coast, 4229

Tel: +61 7 5595 4194 Email: buhrec@bond.edu.au

Dr. Mark Edwards (Supervisor) James Champion (PhD Candidate)

Appendix B

Participant Consent Form

School of Psychology

Participant Consent Form for Participants in the

Psychology Cognition Laboratories

The research carried out in the Psychology Cognition Laboratories includes a number of new and continuing research projects. Our studies are concerned with understanding more about the nature of emotion and cognitive processes. The success of our research is vitally dependent upon the assistance of volunteers like yourself, and we are extremely grateful for your participation.

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Bond University Human Research Ethics Committee
C/O Office of Research Services
Bond University, Gold Coast, 4229

Tel: +61 7 5595 4194 Email: buhrec@bond.edu.au

I consent to participating in this research project:

Print name: _____

Signature: _____ Date: _____

Appendix C

Researcher-Constructed Demographics Questionnaire

Please answer the following questions as accurately as possible. All of your responses will remain confidential.

1. What is your current age in years? _____ years

2. Please indicate your gender by circling the appropriate response:

   Male Female

3. Starting from your first year of primary school, how many years of formal education have you completed?

   _____ years

4. What is your current employment status? (please circle)

   Student Unemployed Employed Self-employed Retired

5. Are you left or right handed (please circle)

   Left Right

6. Do you suffer from blurred or impaired vision? Y N

7. Is your current vision normal or been corrected to normal? Y N

8. Do you consider members of the *opposite* gender to be sexually appealing? Y N

Appendix D

State-Trait Anxiety Inventory (STAI; Spielberger et al., 1983)

State Anxiety Scale

A number of statements that people have used to describe themselves are given below. Read each statement carefully and then circle the appropriate number to the right of the statement to indicate how you feel *right now*, that is, at this moment. The scoring key is indicated below. There are no right or wrong answers. Do not spend much time on any one statement but give the answer that seems to describe your current feelings best.

		NOT AT ALL	*SOMEWHAT*	*MODERATELY*	*VERY MUCH SO*
1	I feel calm	1	2	3	4
2	I feel secure	1	2	3	4
3	I am tense	1	2	3	4
4	I feel strained	1	2	3	4
5	I feel at ease	1	2	3	4
6	I feel upset	1	2	3	4
7	I am presently worried over possible misfortunes	1	2	3	4
8	I feel satisfied	1	2	3	4
9	I feel frightened	1	2	3	4
10	I feel comfortable	1	2	3	4
11	I feel self-confident	1	2	3	4
12	I feel nervous	1	2	3	4
13	I am jittery	1	2	3	4
14	I feel indecisive	1	2	3	4
15	I am relaxed	1	2	3	4
16	I feel content	1	2	3	4
17	I am worried	1	2	3	4
18	I feel confused	1	2	3	4
19	I feel steady	1	2	3	4
20	I feel pleasant	1	2	3	4

Trait Anxiety Scale

A number of statements that people have used to describe themselves are given below. Read each statement carefully and then circle the appropriate number to the right of the statement to indicate how you *generally* feel. The scoring key is indicated below. There are no right or wrong answers. Do not spend much time on any one statement but give the answer that seems to describe how you generally feel.

		ALMOST NEVER	*SOMETIMES*	*OFTEN*	*ALMOST ALWAYS*
21	I feel pleasant	1	2	3	4
22	I feel nervous and restless	1	2	3	4
23	I feel satisfied with myself	1	2	3	4
24	I wish I could be as happy as others seem to be	1	2	3	4
25	I feel like a failure	1	2	3	4
26	I feel rested	1	2	3	4
27	I am “calm, cool and collected”	1	2	3	4
28	I feel that difficulties are piling up so that I cannot overcome them	1	2	3	4
29	I worry too much over something that does not really matter	1	2	3	4
30	I am happy	1	2	3	4
31	I have disturbing thoughts	1	2	3	4
32	I lack self-confidence	1	2	3	4
33	I feel secure	1	2	3	4
34	I make decisions easily	1	2	3	4
35	I feel inadequate	1	2	3	4
36	I am content	1	2	3	4
37	Some unimportant thought runs through my mind and bothers me	1	2	3	4
38	I take disappointments so keenly that I can’t put them out of my mind	1	2	3	4
39	I am a steady person	1	2	3	4
40	I get in a state of tension or turmoil as I think over my recent concerns or interests	1	2	3	4

Appendix E

Picture Stimuli

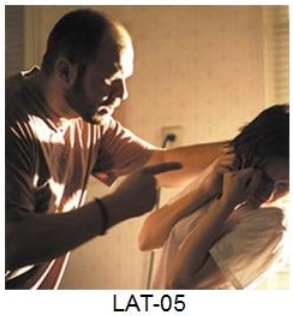
Low Arousing Threatening (LAT)


LAT-01


LAT-02


LAT-03


LAT-04


LAT-05


LAT-06


LAT-07


LAT-08


LAT-09


LAT-10


LAT-11


LAT-12


LAT-13


LAT-14


LAT-15

Low Arousing Appetitive (LAA)


LAA-01


LAA-02


LAA-03


LAA-04


LAA-05


LAA-06


LAA-07


LAA-08


LAA-09

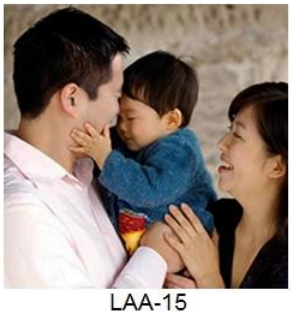

LAA-10


LAA-11


LAA-12

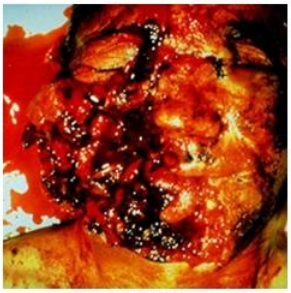

LAA-13


LAA-14

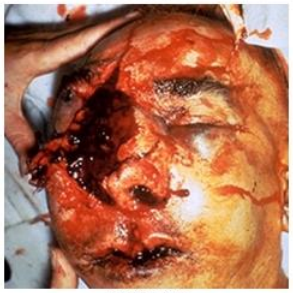

LAA-15

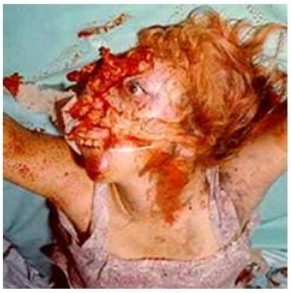
High Arousing Threatening (HAT)

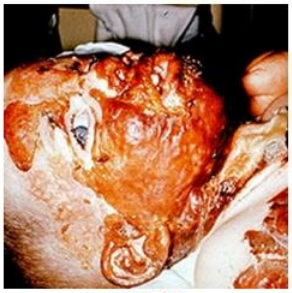

HAT-01


HAT-02


HAT-03


HAT-04


HAT-05


HAT-06


HAT-07


HAT-08


HAT-09


HAT-10


HAT-11


HAT-12


HAT-13


HAT-14


HAT-15

High Arousing Appetitive (HAA)


HAA-01


HAA-02


HAA-03


HAA-04


HAA-05


HAA-06


HAA-07


HAA-08


HAA-09


HAA-10


HAA-11


HAA-12


HAA-13


HAA-14


HAA-15

Neutral (NEU)


NEU-01


NEU-02


NEU-03


NEU-04


NEU-05


NEU-06


NEU-07


NEU-08


NEU-09


NEU-10


NEU-11


NEU-12


NEU-13


NEU-14


NEU-15


NEU-16


NEU-17


NEU-18


NEU-19


NEU-20


NEU-21


NEU-22


NEU-23


NEU-24


NEU-25


NEU-26


NEU-27


NEU-28


NEU-29


NEU-30

Appendix F

Display Layout for the Spatial Cueing Task

Display ratio:	4:3
Resolution:	800 × 600 pixels
Monitor size:	19”
Refresh rate:	85 Hz
Colour resolution:	32-bits

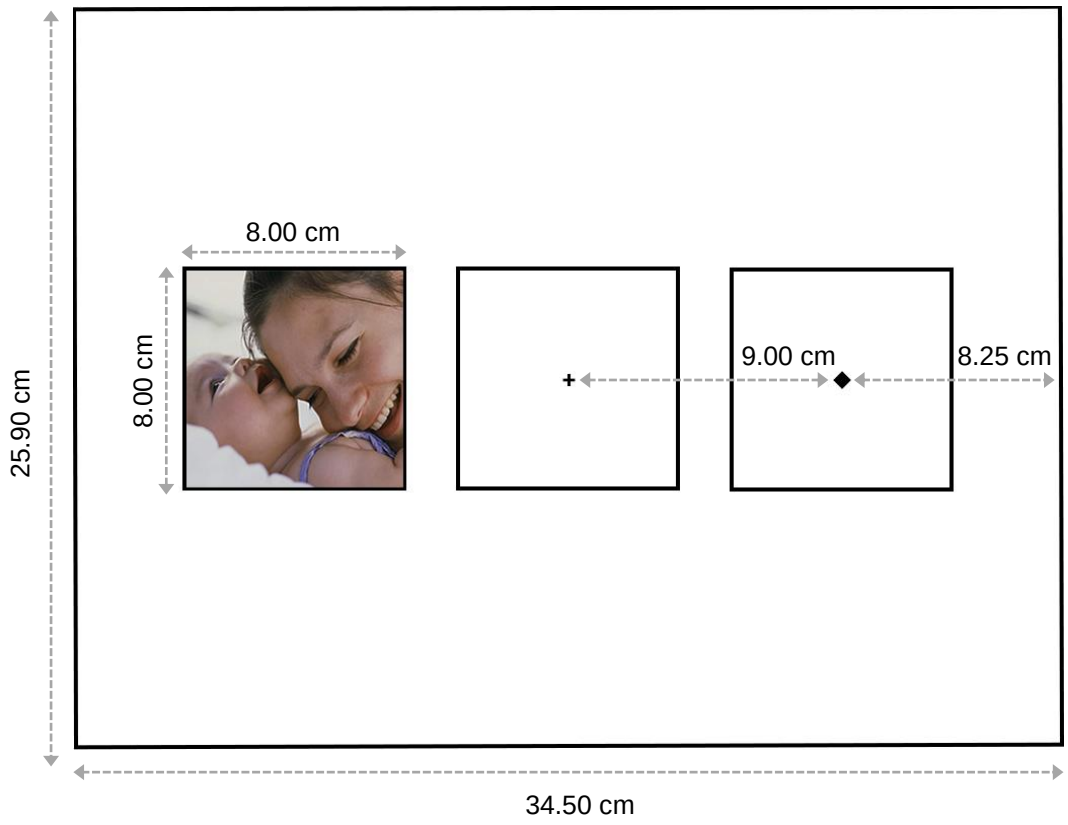


Figure F1. Display layout for the spatial cueing task in Study 2.

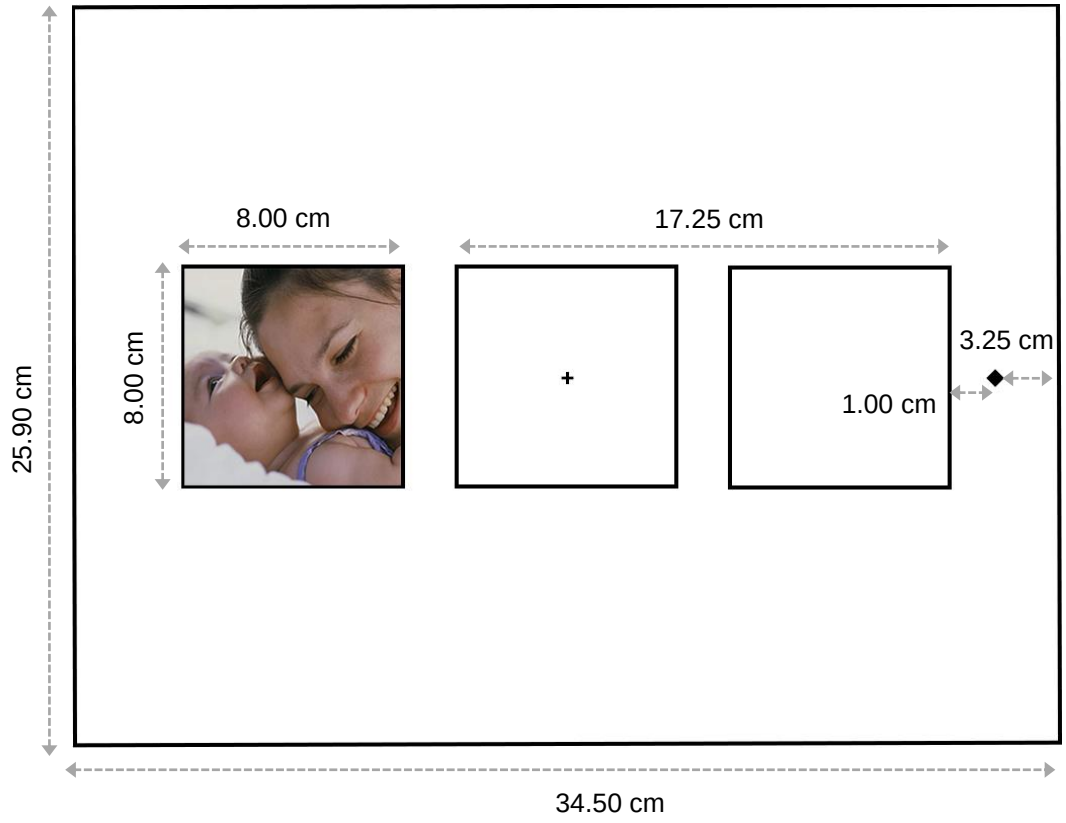


Figure F2. Display layout for the spatial cueing task in Study 3.